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THE LOWER RAPIDS OF THE MISSISSIPPI RIVER[1]

In the early days of navigation on the Mississippi two important rapids were found to interrupt the passage of vessels at low-water stages ; one, about fifteen miles in length, being above the city of Rock Island, Ill., and the other, about eleven miles in length, above the city of Keokuk, Ia. These became known respectively as the upper and lower rapids. The latter are also called the Des Moines Rapids, because of the situation above the mouth of the Des Moines River. In both rapids the obstructions consist of rock ledges, yet the form or arrangement of the ledges is not the same. The upper rapids consist of a succession of rock barriers called "chains," each usually but a fraction of a mile in breadth, which pass across the river channel and are separated by pools or stretches of slack water. The lower rapids are more uniform, there being a nearly continuous descent across them. The rate of descent, however, varies, as shown below. In opening the upper rapids to navigation it was necessary only to cut channels across the barriers, while in the lower rapids a canal has been constructed. This consists of a channel blasted out of the rock for a distance of three and a half miles from the head of the rapids, below which a retaining embankment is built on the river bed along the Iowa side to the foot of the rapids at Keokuk.

The precise length of the lower rapids is 11.1 miles, the head

[1] Read at Thirteenth Meeting of Iowa Acad. Science at Des Moines, December 28, 1898. Published by permission of the Director of United States Geological Survey.

being at Montrose Island and the foot a short distance above the river bridge at Keokuk. The total descent is 22.17 feet, or very nearly two feet per mile. The rate of descent is greatest in the lower part, there being a fall of about 4¼ feet in the lower mile and nearly eight feet in the lower two miles. From Greenleaf's[1] report on "Water Power of the Mississippi and Tributaries," the following data are obtained. "In the first 4800 feet from the lower lock there is a rise of 4.21 feet, then 2.22 feet in the next 3600 feet, and 1.67 feet in the succeeding 3600 feet to the middle lock, making the fall in ordinary low water from a point opposite the middle lock to the foot of the rapids 8.1 feet." Above this part, the fall, though not uniform, is less definitely broken into rapids and pools than in the upper rapids. Indeed, there appears to be a rock floor forming the river bed throughout the entire length of the lower rapids.

Immediately above the head of the lower rapids a deep preglacial channel appears, whose floor, as shown by several borings, is 125 to 135 feet below the low-water level of the river. This is filled mainly with blue bowlder clay up to about the level of the river bed. Sand, however, in places, extends to a depth of nearly sixty feet below the surface of the river at low water, as shown by the bridge soundings at Ft. Madison and Burlington. A pool extends from the head of the rapids up to the vicinity of Ft. Madison, nine miles. The depth of the pool in places exceeds twenty feet at low-water stage, thus extending to about that distance below the level of the rock surface in the river bed at the head of the rapids.

Below the rapids the river for four miles is in a narrow valley, in which the depth of the drift-filling is not known. It there enters a broad preglacial valley, which has been found to constitute the continuation of that occupied by the river above the rapids, and which no doubt was excavated to a corresponding depth, though as yet no borings have been made which reach its rock floor. The comparative size of the valley of the Mississippi in its new channel across the lower rapids, and the par-

[1] Tenth Census of United States, 1880, Vol. XVII, p. 60.

tially abandoned preglacial valley, is shown in cross-section in Fig. 1, furnished by the Iowa Geological Survey. The depth

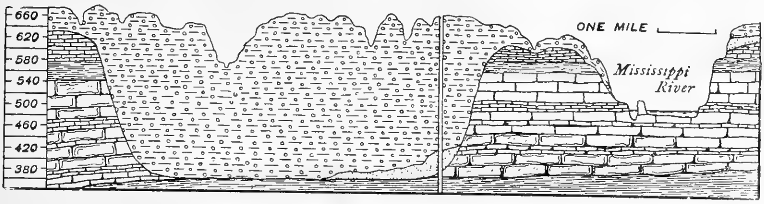

FIG. 1. Cross-section from Sonora, Ill., to Argyle, Ia., showing old and new channels of the Mississippi River (Iowa Geol. Survey).

of the new channel is but little more than half, and the width scarcely one-fifth, that of the preglacial channel. In size it is, therefore, scarcely one-tenth as large as the preglacial valley.

The small size of the Mississippi Valley at the lower rapids, compared with its size above and below, was noted by Worthen more than forty years ago, and interpreted to be an evidence that the greater valley is preglacial, while the portion of the valley across the rapids is postglacial. In the report of Hall, made in 1856, the following statement is found in the discussion of Lee county :[1] "The valley thus scooped out of the solid rocks extends from Montrose to the mouth of Skunk River, and is from six to eight miles in width. The eastern portion of this ancient basin, except the bluffs on the river above Ft. Madison, is now covered by the alluvial deposits before mentioned, while the western part is occupied by deposits of drift material from 100 to 185 feet in thickness. That this valley was formed by ancient currents previous to the drift period is proved by the fact that a considerable portion of it is now occupied by deposits of that age, and which must have been formed after those currents ceased to act." Again, in his first volume of the "Geology of Illinois," published in 1866, Worthen remarks (p. 9) that the present river has shown, by the work done in the upper and lower rapids, how inadequate its erosive power would be to

[1] Geol. of Iowa, Vol. I, 1858, p. 188.

excavate in postglacial time the entire valley, which it now but partially occupies.

A few years later General G. K. Warren discovered the abandoned section of the preglacial valley which crosses Lee county, Iowa, a few miles west of the lower rapids, and connects the portion occupied by the stream above the rapids with that below. In his report in 1878 he presented a discussion illustrated by a map setting forth the position of the old channel.[1] General Warren based his interpretations upon the absence of rock outcrops in the valleys which traverse the old course of the river, there being no borings that extended to the rock bottom. A few years later a boring at Mont Clare, Ia., was sunk in the old valley and brought confirmation to General Warren's interpretation.[2] The accompanying sketch map, Fig. 2, sets forth the position of the old valley and its relation to the one across the rapids.

It should not be inferred that this broad preglacial valley was necessarily a line of discharge for the whole of the present drainage basin of the upper Mississippi. The available evidence concerning the preglacial drainage, though imperfect, is thought to indicate that a large part of the region above the upper rapids may have drained southeastward through the Green River Basin to the Illinois. Hershey has suggested a northward discharge for the headwater portion of the basin, a suggestion which awaits adequate investigation.[3] The preglacial valley which passes the lower rapids on the west is nearly coincident with the present Mississippi from the head of these rapids up to Muscatine, but its position farther north has not been ascertained, nor has the size of its drainage basin been even approximately determined. It is probable, however, that much of eastern Iowa was tributary to this preglacial line.

[1] Report of the U. S. Army Engineers for 1878–9, Vol. IV, Part 2, pp. 916, 917, Diagram E ; also Diagram 1, Sheet 4.

[2] Buried River Channels in Southeastern Iowa, by C. H. GORDON, Iowa Geol. Survey, Report for 1893, pp. 239–255, Figs. 5, 6, and 7. Published in 1895 as Vol. III of the present survey.

[3] American Geologist, Vol. XX, 1897, pp. 246–268.

Date of the deflection across the lower rapids.— In previous years attention has been called, both by Mr. Fultz and myself,

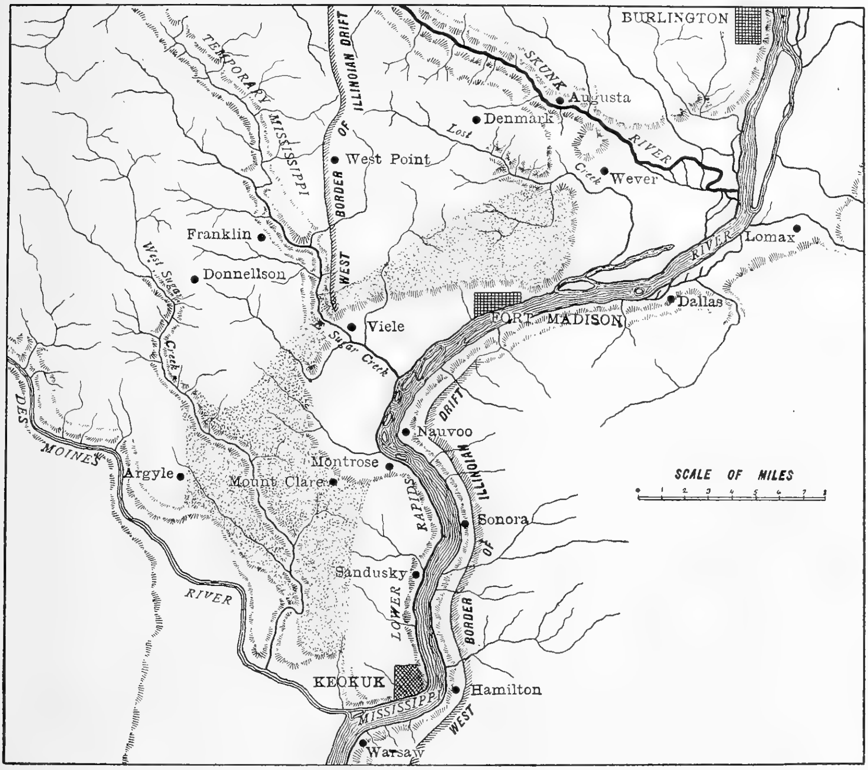

FIG. 2. Sketch map of region discussed, showing course of old channels.

Note of Explanation. — The abandoned portion of the preglacial valley of the Mississippi is shaded. Hachures are used to indicate valley borders both above and below the level of the high terraces, and along the temporary Mississippi channel, opened at the Illinoian stage of glaciation. The extent of the high terrace south of the Des Moines Valley is not determined.

to evidence that the region around the lower rapids presents a complicated glacial history.[1] It has been shown that one ice-field extended southward from Kewatin, in the Dominion of Canada, across Manitoba, Minnesota, and Iowa, into Missouri,

[1] F. M. FULTZ, Proc. Iowa Acad. Sci. for 1895, Vol. II, pp. 209–212; *ibid.*, 1896,

and that it spread eastward beyond the valley of the Mississippi, from near the southern end of the Driftless Area of the upper Mississippi to the vicinity of Hannibal, Missouri. Two invasions may have been made by that ice-field with an intervening deglaciation interval of some length, as indicated by Bain.[1] The later and probably the more extensive advance is referred to the Kansan stage of glaciation. It has also been shown that subsequent to the Kansan stage of glaciation an ice-field extended from Labrador and the heights south of Hudson Bay, southwestward across Michigan, the Lake Michigan Basin, and Illinois into southeastern Iowa.

The Kewatin ice-field not only covered the preglacial valley near the lower rapids, but also the district which the stream traverses in passing the rapids. It was thus liable to have displaced the stream to a much greater extent than the deflection past the rapids, as indicated below. The invasion from Labrador, on the other hand, appears to have barely reached to the rapids and may not have interfered seriously with drainage across them, though it greatly disturbed the course of the Mississippi above the rapids. It did not reach the section of the preglacial valley west of the rapids. The deflection from the preglacial channel must, therefore, be due to the Kewatin ice-field.

But since the Kewatin ice-field may have twice invaded this region it is necessary to inquire into the probable effect of each of its two invasions. If it be found that the earlier invasion extended beyond the line of the preglacial valley and deposited sufficient material to prevent the reëstablishment of the river along the preglacial line, some deflection at this early date must have occurred. The deflection, however, need not necessarily have thrown the stream into its present course across the rapids. That course may have been taken as a result of the later invasion of the Kewatin ice-field, if not as a result of the still later

Vol. III, pp. 60–62; FRANK LEVERETT, Science, January 10, 1896; American Geologist, February 1896; Bull. No. 2, Chi. Acad. Sci., May 1897; Proc. Iowa Acad. Sci., 1897, Vol. V, pp. 71–74.

[1] Proc. Iowa Acad. Sci. for 1897, Vol. V, pp. 86–101.

encroachment of the Labrador ice-field. It is reasonable to suppose that the deflection caused by the Kewatin ice-field might give the stream a course farther to the east than the lower rapids, since the region across which the rapids have been opened appears to have been entirely covered by the Kewatin ice-field at each of its invasions. It will be necessary, therefore, to determine whether the Kewatin field did not establish the Mississippi in a course east of the rapids, and whether that course was not held by the Mississippi until the Labrador ice-field forced it westward into its present course across the lower rapids.

Turning now to the question of the influence of the supposed earlier invasion of the Kewatin ice-field, a few remarks seem necessary concerning the deposits made by that ice-field. The lowest conspicuous member of the drift series in eastern Iowa is a sheet of dark blue till, often nearly black, which is thickly set with fragments of wood and coal. This is overlain by a sheet of blue-gray till, which differs from the blue-black till in texture and rock constituents, as well as in color. It shows a decided tendency to break into rectangular blocks and often presents vertical fissures, extending to a depth of many feet, which are filled with sand and deeply oxidized clay. The blue-black till is very friable and seldom shows a tendency to break into rectangular blocks, while the few fissures which it contains traverse it in oblique rather than vertical lines. The blue-gray till carries much less vegetal material and coal fragments than the blue-black till. It differs also from the blue-black till in containing a larger percentage of greenstone rocks. These differences have naturally led to the suspicion that two quite distinct sheets of till are present, and this suspicion is confirmed by the occasional occurrence of a black soil at the surface of the blue-black till. Such exposures are rare compared with those of the Yarmouth soil, found between the Kansan and Illinoian till sheets,[1] but their rare occurrence may not demonstrate that the interval of deglaciation is of minor importance. From conversations with Calvin, Norton, and Bain, I am led to think that a large part of

[1] See JOUR. GEOL., Vol. VI, 1898, pp. 81–85.

the buried soils, reported by McGee from eastern Iowa,[1] occupy a horizon corresponding to the junction of the blue-gray and blue-black tills of southeastern Iowa. This being true the interval of deglaciation between the blue-gray and blue-black tills becomes of much importance.

The sheet of blue-black till has been found to occur at points farther east than the lower rapids. It occurs in the Mississippi valley in the vicinity of Ft. Madison, Iowa, and in Hancock and Adams counties, Illinois, east and southeast of the rapids. There is little doubt, therefore, that during the deposition of this till the Kewatin ice-field was *sufficiently extensive* to force the Mississippi out of the preglacial channel which passes west of the lower rapids.

It is not certain, however, that the *amount of filling* in that valley was sufficient to prevent the return of the stream to its preglacial course in the interval between the deposition of the blue-black till and the blue-gray till. The blue-black till in the vicinity of Ft. Madison is found to rise to a height of only sixty to seventy-five feet above the present stream, or nearly seventy-five feet less than would probably have been necessary to throw the stream from the preglacial channel into its present course across the rapids. This may possibly have been sufficient to throw the drainage of the portion above the lower rapids eastward into the Illinois, either by way of the Green River basin or by some line farther south, that is now completely concealed by the later sheets of drift. But it seems quite as probable that the stream returned to its preglacial course.

The blue-gray till seems to be fully as extensive a sheet as the underlying blue-black till. It extends eastward into Illinois beneath the Illinoian till sheet an undetermined distance. The tendency to break into rectangular blocks often serves to distinguish it from the overlying Illinoian till, as well as from the underlying blue-black till, though the Illinoian in places takes on this phase of fracture. Probably the most extensive of the

[1] Eleventh Annual Report, U. S. Geol. Surv., 1889–90, pp. 232, 233, 485–496, 541, 569.

exposures of the blue-gray Kansan till are found in the vicinity of Ft. Madison. They there constitute for several miles the upper 100 feet of the Mississippi bluff, except a thin coating of loess.

The filling produced by the blue-gray till was sufficient to prevent the return of the stream to its preglacial course, the altitude of the surface along the part of the preglacial channel west of the lower rapids being as great as in border districts. In this case, therefore, it is only necessary to decide whether the stream assumed its present course across the lower rapids at the time the Kewatin ice-field made its final withdrawal from that region, or whether it drained eastward to the Illinois until it was forced from that course by the advance of the Labrador ice-field, at the Illinoian stage of glaciation. Concerning this question it is thought that evidence of some value has been collected, as appears below.

Erosion preceding the Illinoian stage of glaciation.—The Mississippi valley for about fifty miles below the lower rapids was greatly filled by the drift from the Kewatin ice-field. Immediately below the rapids the filling on the borders of the valley reached a level about 150 feet above the present stream. It seems not improbable that there was a filling to nearly this height in the middle of the valley, for the abandoned section just above was filled in its middle part to as great a height as on its borders. Upon passing down the valley the height of filling gradually decreases to the limits of the Kewatin drift near Hannibal. From the filling of tributaries near Hannibal it is estimated that the Mississippi valley could not have been filled to a height greater than seventy-five feet above the present stream. Below Hannibal the filling was produced by stream action rather than by glacial deposition and appears to have reached but little, if any, above the sand terraces of the valley, say fifty feet above the river. Now if this filling suffered but little erosion before the Illinoian stage of glaciation, it can reasonably be inferred that the drainage of the upper Mississippi did not pass across the lower rapids and through this part of

the valley until forced westward by the advance of the Labrador ice-field. But if a great erosion took place in this part of the valley prior to the Illinoian stage of glaciation there would seem good grounds for supposing that the stream assumed its present course soon after the Kewatin ice-field made its final withdrawal.

Examining into this question it is found that after this drift was deposited by the Kewatin ice-field, an erosion so great took place that it was removed throughout the greater part of the width of the valley down to a level scarcely fifty feet above the present stream at the mouth of the Des Moines, and to an equally low level at Hannibal. The depth of cutting appears, therefore, to have been about 100 feet at the mouth of the Des Moines, and perhaps twenty-five feet at Hannibal. It seems safe to assume an average depth of fifty feet for the entire section and a width of five or six miles, making an erosion of nearly three cubic miles of drift in the fifty miles below the mouth of the Des Moines River. It is scarcely necessary to raise the question whether this erosion could have been accomplished by the Des Moines and other tributaries of the Mississippi below the rapids, for it is evidently out of proportion to the work which these small streams would be able to accomplish since the Kansan stage of glaciation. It seems certain that the Mississippi River is responsible for the principal part of the erosion. This makes necessary the opening of the new channel across the rapids, for the old channel west of the rapids was not utilized by the river after the Kansan stage of glaciation, and no other line of drainage could have been adopted by the river that would pass through the portion of the valley below the rapids.

Evidence is found within the new channel, of an erosion such as the interpretation just given demands. In the south part of Keokuk, between the foot of Main Street and the mouth of Soap Creek the rock bluff rises but fifty to sixty feet above low water, and is capped by a bed of bowlders about twenty feet in depth. Attention was called to this bed some thirty years ago by Mr.

S. J. Wallace, of Keokuk,[1] and the view expressed that it is "old river shingle." Mr. Wallace stated that Dr. George Kellogg, of Keokuk, regarded it as the indication of an old fall at this place, but that he did not so regard it. This bed has been discussed at some length by Dr. C. H. Gordon in the Geology of Iowa,[2] and three interpretations for its origin are presented. (1) That it was formed by river action alone, *i. e.*, as an alluvial bar; (2) that it is due to the cutting down of a till sheet, the coarse material being left as a residue; (3) that it is a bowldery moraine dropped at the edge of the ice sheet at the Illinoian stage of glaciation.

Of the three interpretations the second seems to Mr. Gordon, as well as to the present writer, the most applicable. Dr. Kellogg's suggestion of a fall as the cause seems at least to be poorly sustained. A similar bowlder bed occurs near Warsaw, Ill. It there forms the capping of an eroded till surface and bears clear evidence of removal of the fine material by a stream and the retention of the bowlders as a residue. A bowlder bed is also found along the face of the west bluff of the rapids near Sandusky, about six miles above Keokuk, at a level forty to sixty feet above the stream, that probably was derived from the erosion of a sheet of till. It seems referable to the period of erosion that produced the beds at Keokuk and Warsaw. The exposure, however, is not sufficiently extensive to show clearly its relation to the till sheet.

The amount of erosion effected is so great that the beginning of this new channel seems to date from near the close of the Kansan stage of glaciation. This becomes more evident as we study into the later stages of the history of the river. Even if the river had been forced into a channel farther east than the lower rapids, it seems scarcely probable that it remained long in that course. It apparently began its work of opening the course across the rapids long before the Labrador ice-field had reached the region.

[1] Proc. A. A. A. S., Vol. XVII, 1869, p. 344.

[2] Geology of Iowa, Vol. III, 1893, pp. 252–255.

Filling at the Illinoian stage of glaciation.— Following this great erosion there came a partial filling of the part of the valley immediately outside the limits of the Illinoian drift sheet. It is well displayed below the rapids, and some remnants are to be seen along the borders of the rapids. This filling appears to have occurred at the Illinoian stage of glaciation. Evidence of this relationship is to be found in the connection, or close association, of this filling with the opening of a temporary course for the Mississippi across southeastern Iowa, which occurred at the time the Mississippi valley above the rapids was covered by the Labrador ice-field.

The drainage line referred to leaves the present Mississippi at the mouth of the Maquoketa, passes southward along that valley (reversed) to "Goose Lake channel," and thence to the Wapsipinnicon Valley, connecting with it a few miles above its present mouth. It follows up the Wapsipinnicon a few miles to the mouth of Mud Creek, a southern tributary, which, together with a small tributary of Cedar River, also called Mud Creek, furnishes the line of continuation for the old valley to the Cedar River near the great bend at Moscow. The valley continues southwest to the Iowa River along the course now followed by the Cedar in its lower twenty-five miles. It then passes southward from Columbus Junction to Winfield, and thence westward to Skunk River at Coppock, opening in its westward course two lines, one of which is now utilized by Crooked Creek. From Coppock the old drainage line follows the course of Skunk River southward to Rome, and Cedar Creek (reversed) to Salem. It there turns southeastward, being known as "Grand Valley" in northern Lee county, and joins the Mississippi about six miles west of Fort Madison, nearly opposite the head of the rapids. Its continuation was evidently across the rapids into the broad valley below Keokuk.

The altitude of the bottom of this old valley, near the head of the rapids, is fully 100 feet above the present stream, but connects well with the surface of the valley filling in and below the rapids. It is nearly 100 feet lower than at the point where it

leaves the Iowa valley, 75 miles to the north. The portion above the point where the Iowa is crossed has been so modified since the Illinoian stage of glaciation, that very little is known concerning its condition at the close of that glacial stage, but the portion south from the Iowa valley has been only slightly modified.

Very little material was deposited on the bed of the temporary channel of the Mississippi in the 75 miles from the Iowa valley to the head of the rapids, but a great filling occurred in the broad valley below, and some filling along the rapids, espeally at their lower end. The valley which, at the foot of the rapids, had been cut down to a level scarcely 50 feet above the present stream, was built up to 80 or 90 feet above the river at that point. The depth of filling is found to decrease upon passing down the valley and becomes scarcely noticeable at Hannibal. It is, therefore, much like a delta, formed where a rapid stream emerges into a sluggish lake-like body of water. It consists mainly of fine material, sand or silt, with few pebbles greater than ¼ inch in diameter. A fine gravel, however, appears at an exposure called "Yellow Banks" near the mouth of the Des Moines River. The bowlder bed in Keokuk, described above, received at this time a capping of sand 15 or 20 feet in depth. Sand deposits are also found at a corresponding level in Hamilton, Illinois, near the foot of the rapids, capping a low part of the rock bluff. Another possible remnant of the sand filling is found at Sandusky, Iowa, six miles above Keokuk, immediately back of the bowlder-strewn slope, noted above. It there rises about 80 feet above the river or to within 25 feet of the level of the bottom of the channel of the temporary Mississippi, ten miles to the north. No remnants of the filling have been noted in this interval of 10 miles, and it is thought probable that the rate of fall was so great above Sandusky that but little lodgment of material occurred.

In the portion of the Mississippi valley covered by the Labrador ice-field, at the Illinoian stage of glaciation, there appears to be no such sand filling as is found below the rapids, thus con-

firming strongly the above interpretation, that the sand filling occurred during this stage of glaciation.

In explanation of the small amount of material deposited in the bed of the temporary Mississippi, Professor Chamberlin has suggested to me, that the ground in which this channel was excavated may have been frozen at the time of excavation, its situation being on the immediate borders of the ice-sheet. and that this frozen condition of the ground may have prevented the stream from eroding more material than it could readily transport.

The time involved in the valley filling is a question of much interest, but one on which an estimate is very difficult to make. The filling of any given section is not the measure of the full work of the stream, but simply an index of the excess of material above the limits of transportation by the stream. To properly estimate the work in a stage of filling, it is necessary to compute the amount of material carried through the channel, as well as that deposited in it. It is doubtful if present methods of study are sufficiently refined to enable one to make even an approximate calculation of the time involved. It may safely be affirmed, however, that the filling under discussion progressed slowly, and that the time involved was sufficiently long to affect materially the chronology of the lower rapids.

Erosion conditions during the Sangamon interglacial stage.—Between the Illinoian stage of glaciation and the deposition of loess which accompanied the Iowan stage of glaciation, there was a long interval of time, during which the surface of the Illinoian drift sheet was subjected to leaching and weathering, and the formation of a soil. The name Sangamon has been applied by the present writer to the soil and weathered zone formed at this time, and may properly be made to denote the time interval.[1] Although the degree of weathering and leaching makes it evident that the interval was protracted, the valley excavation appears to have been comparatively slight, so far as depth is

[1] Proc. Iowa Acad. Sci., Vol. V, for 1897, pp. 71–80. JOUR. GEOL., Vol. VI, 1898, pp. 171–181.

concerned. This is true, not only in the region about the lower rapids, but throughout the entire exposed portion of the Illinoian drift sheet.

The erosion on the lower rapids appears to have been scarcely sufficient to remove the sand filling which occurred during the Illinoian stage of glaciation. It could have amounted to scarcely 20 feet in depth and was mainly in loose material. The limits of the erosion are determined by the level down to which the loess extends. That deposit appears nowhere *in situ* at a lower level than 65 to 70 feet above the head of the rapids. Its lower limits in the portion of the valley above the rapids are also as great as 70 feet above the present stream.

A study of tributary valleys in this region has shown that the streams meandered widely and performed a large amount of work, notwithstanding the shallow depth of erosion. For example, Skunk River, in southeastern Iowa, at that time meandered over a width of about two miles (see Fig. 2), whereas it is now confined to an inner valley scarcely one half mile in average width. It should be noted, however, that the erosion of fifteen or twenty feet, over a width of two miles, by a stream with sluggish current, may involve more time than is required for the cutting of the inner valley, which has an average depth of nearly 100 feet and a width of about one-half mile. In this interval, as in the interval of filling which preceded it, the rapids suffered but little modification, yet the time involved was sufficiently long to affect materially the estimates of the duration of the stream in its present course.

The loess filling accompanying the Iowan stage of glaciation.—The period of low gradient and slack drainage, just discussed, was followed by even less favorable conditions for the opening of a channel. During the Iowan stage of glaciation, as long since pointed out by McGee,[1] and elaborated by Calvin and others,[2] the deposition of a sheet of silt occurred, not only along

[1] The Drainage System and Distribution of the Loess of Eastern Iowa, by W J McGee, Bull. Washington Phil. Soc'y, 1883, Vol. VI, pp. 93–97. Also, see discussion in Eleventh Ann. Rep. U. S. Geol. Surv., 1889–90, pp. 435–471.

[2] Geology of Jones County, by S. Calvin, Iowa Geol. Surv., 1895, Vol. V, pp.

the main valleys, but over much of the low country in the interior of the Mississippi basin. This silt is the problematical loess. Its mode of deposition is still a matter of dispute, the deposit being thought by some glacialists to be largely aqueous, while by others it is thought to be chiefly æolian.

In the region under discussion the valleys, as previously indicated, were opened only to shallow depths, hence only a slight accumulation of the silt was necessary to fill them, or to cause the streams to spread over the bordering plains. The depth of the silt in the vicinity of the lower rapids seldom reaches thirty feet, and probably averages not more than fifteen feet. Its bulk, therefore, does not, so far as the valleys are concerned, greatly exceed that of the filling which occurred below the rapids during the Illinoian stage of glaciation. If, however, the deposits on the bordering plains are taken into consideration, the amount of material deposited is very much greater, for the plains were covered to a depth of six to ten feet by this silt.

Whether the deposition took place by water or by wind, there seems to have been a suspension of erosion on the lower rapids, and the length of this suspension must certainly be sufficient to affect materially their duration. An estimate of the time involved seems at present impossible, there being fewer data for an estimate than in the filling which occurred at the Illinoian stage.

Erosion following the loess filling.—After the deposition of the loess, the valleys throughout much of the Mississippi basin experienced a marked deepening, which brought their bottoms to a lower level than before the loess filling. In the portion of the Mississippi valley, which lies within and near the rapids, the deepening seems to have proceeded continuously to a level nearly as low as the present stream, or fifty to seventy-five feet below the excavation which occurred in the interval following the

63–69. Geology of Johnson County, by S. CALVIN, Iowa Geol. Surv., 1896, Vol. VII, pp. 39–45, 86–89. Geology of Linn County, by W. H. NORTON, Iowa Geol. Surv., 1894, Vol. IV, pp. 168–184. Geology of Marshall County, by S. W. BEYER, Iowa Geol. Surv., 1896, Vol. VII, pp. 234–238. Geology of Plymouth County, by H. F. BAIN, Iowa Geol. Surv., 1897, Vol. VIII, pp. 335–351.

Kansan glaciation. This excavation in the section embraced within the rapids was mainly rock, for the loess and alluvium had built up the channel scarcely thirty feet above the rock floor of the post-Kansan erosion. But for some distance, both above and below these rapids, the excavation was largely in till. The channel across the rapids was opened to a width but little greater than the stream, or about one mile. Elsewhere the channel is three to six times the width of the stream.

This erosion seems to have continued until the early part of the Wisconsin glacial stage, when, as indicated below, another filling occurred. The extent and depth of the erosion which took place prior to the Wisconsin filling is well shown in the broad portion of the valley above the rapids. Numerous wells indicate that the till had been removed nearly to present river level over the greater part of the width of the valley before that filling set in.

The amount of erosion in the Mississippi valley seems to have been nearly as great in this interval as in the post-Kansan interval of erosion. It is doubtful, however, if the time involved was so great as in that interval, for the gradient appears to have been higher. To properly estimate the time involved, it is necessary, also, to know the volume of water discharged through the valley at each interval, a matter concerning which very little is yet known.

Filling at the Wisconsin stage of glaciation.—At the Wisconsin stage of glaciation the Mississippi and several of its tributaries, which flowed away from the ice-sheet, became so burdened by glacial detritus that they were unable to completely transport their load, much less to continue the erosion of their valleys. The Mississippi headed in the ice-sheet near St. Paul, Minnesota, while the Chippewa and Wisconsin rivers brought material from the Chippewa and Green Bay lobes of Wisconsin. Rock River, also, brought material from the Green Bay lobe, and through its tributaries, Kishwaukee and Green rivers, from the Lake Michigan lobe. Just above St. Louis the Illinois River contributed a large amount of material derived from the Lake Michigan lobe.

These streams discharged such large quantities of sand into the Mississippi that the valley was greatly filled as far down as the head of the broad valley of the lower Mississippi at Cairo. Throughout much of the interval between St. Paul and Cairo the valley was filled to a height of fifty to seventy-five feet above the present stream. In the vicinity of the rapids it reached nearly fifty feet above the level of the erosion in the preceding stage of deglaciation.

The filling probably began during the early part of the Wisconsin stage of glaciation, but the great bulk of it appears to have been contributed during the part of the Wisconsin represented by the Kettle morainic system. The transportation of sand down the valley no doubt continued for a long time after the ice-sheet had ceased to contribute material to the headwaters of the present Mississippi. The filling may, therefore, have occupied a longer time than that involved in the formation of all the moraines which cross the headwaters of the Mississippi.

The greater part of this filling consists of sand of medium coarseness. This, however, is interbedded with thin deposits of very fine gravel, and pebbles are also scattered through the sand. The pebbles seldom exceed one half inch in diameter and are usually one fourth inch or less. They have been noted by the writer as far down the valley as the vicinity of Quincy, Illinois. They are a conspicuous feature above Rock Island, Illinois. Upon following up the tributaries of the Mississippi toward the head of these valley trains, the material becomes markedly coarser, as is to be expected on the theory of their derivation from the ice-sheet.

It scarcely needs to be stated that so great a filling has greatly interrupted the removal of the rock barriers of the Mississippi at each of the rapids. A stream with the present volume of the Mississippi and its comparatively low gradient of about six inches per mile, can scarcely do more than remove the material brought in by its tributaries, to say nothing of removing the great amount of material deposited at the Wisconsin stage of glaciation. There appears, however, to have been a long period succeeding

this sand deposition in which the volume of the Mississippi was much greater than at present, and this matter will next receive our attention.

Erosion accomplished by the Lake Agassiz outlet.—Following this period of sand deposition the Mississippi valley afforded a line for the discharge of a large area now tributary to Hudson Bay, an area which was occupied by the glacial Lake Agassiz. The area of this glacial lake and of the country tributary to it is estimated by Upham to have been from 350,000 to 500,000 square miles.[1] This great drainage area has been reduced to about twelve thousand square miles[2] now tributary to the Mississippi through the Minnesota River. The present drainage area of the Mississippi above the lower rapids does not exceed 125,000 square miles, or about one-third the minimum estimate of Upham for the area of Lake Agassiz and its tributaries. Although this great reduction has been in the arid portion of the old drainage basin, it must greatly affect the volume of the river. The present run-off of that region can scarcely furnish a full index, since the ice-sheet was also a great contributor of water to the glacial lake. In addition to the change of drainage area involved in the glacial Lake Agassiz, it is necessary to take into consideration the influx of water from the glacial lake which occupied the western end of the Lake Superior basin, and also a small glacial lake at the head of Green Bay, Wisconsin.

It can scarcely be questioned that at the height of the discharge from Lake Agassiz the volume of water was fully four times that of the present Mississippi. This view is sustained, both by the amount of erosion which took place and by the low gradient reached by the stream. The sand which was deposited as a glacial out-wash while the ice-sheet occupied the head waters of the present Mississippi, was largely removed by the Lake Agassiz outlet, throughout the entire distance from St. Paul to Cairo. It is estimated that the average width of the channel

[1] "The Glacial Lake Agassiz," by WARREN UPHAM, Monograph XXV, U. S. Geol. Survey, 1895, pp. 50–64.

[2] Warren's Report, Bridging Mississippi River, Chief of Engineers U. S. Army, 1878–9, Vol. IV, p. 924.

formed by this outlet is three miles, or about four times the breadth of the present stream.

The depth of erosion seems to have been such as to give portions of the stream a lower level and a lower gradient than that of the present river. This is especially noticeable in the portion above the upper rapids, as indicated by General Warren.[1] Lake Pepin, an expansion of the Mississippi, situated just above the mouth of the Chippewa River has a depth of about sixty feet. It was General Warren's opinion that when the flow of water from the great northern basin ceased, there would no longer be the volume of water necessary to remove the deposits brought in by the Chippewa River. In consequence of this change the Mississippi has been lifted to a level about sixty feet above its former bed. Evidence of a similar filling, produced by the Mississippi at the mouth of the Minnesota, is cited by General Warren. He also noted evidence of the marked shoaling of the Mississippi at the mouth of the Wisconsin. He further expressed the opinion that the entire cutting now in progress on the Mississippi may be confined to short sections in the vicinity of the rapids.

It is of interest to note what a slight change is required to stop the cutting at these places. A filling of only twenty-five feet at the mouth of the Des Moines, or of Rock River, is necessary to cause the neighboring rapids to become protected from erosion. It is not probable, however, that either of these tributaries will for some time, begin the filling of the valley at the foot of the rapids, for the fall of the Mississippi, in passing each of the rapids, is greater than that of the lower course of the Rock, or the Des Moines. Furthermore the main stream has the advantage of much greater volume than these tributaries, in consequence of which the fall across the rapids must be reduced below that of the tributaries before filling can begin at their mouths.

Contours of the bluffs along the lower rapids.—The great length of time involved in the development of a channel across the rapids is shown by the contours of the bluffs. Except at a few

[1] Op. cit., pp. 911–916.

points where the river in rounding a curve has recently encroached upon its bluff there is not an abrupt face. A large part of the slope is so gradual that it has been brought under cultivation. When it is considered that the bluff is composed mainly of a firm limestone, the height of the rock portion ranging from 50 up to 150 feet, with an average height of nearly 100 feet, the prevalence of a moderate slope must indicate a long period of excavation.

But little is yet known concerning the manner in which the rock barrier has been cut away, whether by the recession of a fall, or by the present process of slow cutting across its whole breadth. The fact that the old valley below the rapids was filled with drift about to the height of the highest part of the rock barrier, lends support to the view that there has been a slow cutting down of the entire width of the barrier, rather than the recession of a fall. It seems scarcely probable that the till beneath the stream was scooped out to a much greater degree below the rock barrier, in the early stages of excavation, than at the present day.

Comparison with the upper rapids. — The work performed in cutting away the rock barrier at the lower rapids appears to be several times as great as at the upper rapids. In the latter, the rock excavation has not been sufficient to remove the prominent parts of the barrier. It scarcely amounts to an average cutting ten feet in depth, or one fortieth of a cubic mile. In the rapids under discussion, the barrier is estimated to have suffered a rock excavation to a depth of nearly one hundred feet, or about one fourth of a cubic mile. This difference in amount of work accomplished is readily accounted for by the earlier date at which the lower rapids began excavation. The excavation, as shown above, appears to have been begun soon after the Kansan stage of glaciation, while the excavation at the upper rapids appears to have begun after the Illinoian and to have been mainly accomplished since the Iowan stage of glaciation.

The lower rapids as a chronometer. — When this investigation was entered upon by the writer, hopes were entertained that the

channel across the lower rapids would furnish a valuable chronometer for determining the time since the Kansan stage of glaciation. But from what has been shown, it is evident that the determination of the time is at present very difficult, if not impracticable. It may be thought that this channel will furnish a chronometer for the relative dates of the Kansan, Illinoian, Iowan, and Wisconsin glaciations. But on this question scarcely more than a very rude approximation is likely to be reached. As indicated above, the work involved in filling is very difficult to determine. These difficulties, however, are no greater than those involved in the estimates of the changes of drainage area which the Mississippi has experienced. The object of the present paper is accomplished if the complexity of the history has been adequately presented. The chronological determinations must be deferred to a time when more refined methods of investigation are instituted than are now at command.

FRANK LEVERETT.

THE NEWARK ROCKS OF NEW JERSEY AND NEW YORK[1]

The Newark rocks extend across the northern part of New Jersey, forming a belt which is about thirty-two miles wide

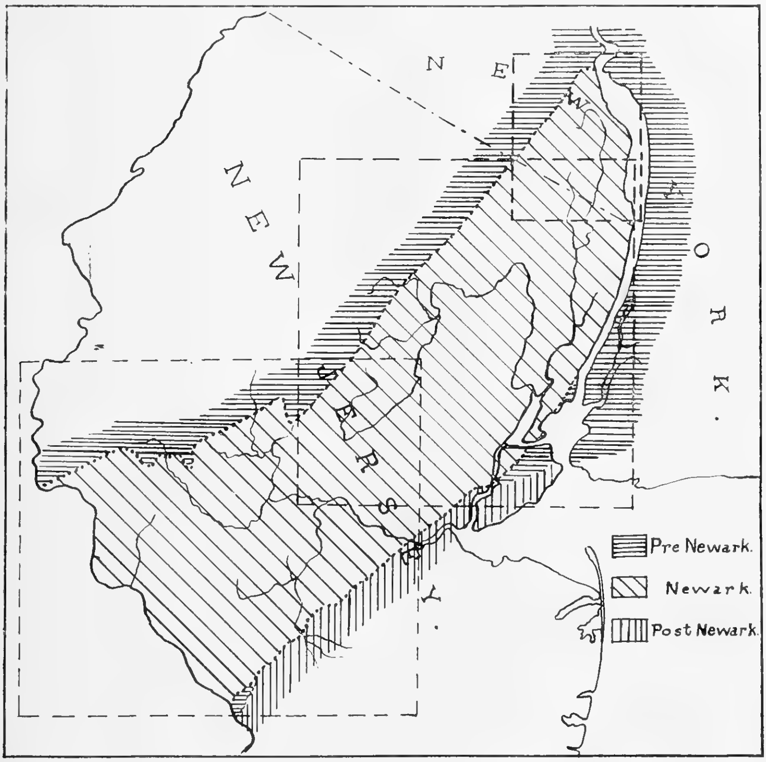

Fig. 1.—Newark area of New Jersey and New York.

along the Delaware River, and fifteen miles wide at the New York state line. In Rockland county, New York, the Newark area forms a right triangle, the apex of which is near Stony

[1] More detailed accounts are given in the following papers: Annual Report of

Point and the hypotenuse along the Hudson River. The southeastern boundary from Trenton northeastward to Staten Island is for the most part formed by overlying beds, Cretaceous and younger. Near Trenton, however, the underlying Philadelphia gneiss outcrops for a few miles. The waters of the Kill von Kull, New York Bay and Hudson River form the boundary from Staten Island northward. The northwestern boundary is irregular and is formed entirely by older rocks — crystallines and Paleozoic shales and limestones. The general position of these rocks and their relations to the older and new formations are shown in Fig. 1.

THE ROCKS

The Newark series consists of sedimentary and igneous rocks. The former are chiefly shales, sandstones and conglomerates; the latter, diabase, to which the more general term trap has usually been applied. Along the Delaware River (Fig. 2) the sedimentary rocks are divisible, on lithological grounds, into three groups, which have been called Stockton, Lockatong, and Brunswick.

Stockton group.— The basal beds of the series are found at Trenton where they rest unconformably upon the older crystalline rocks. They consist of (*a*) coarse, more or less disintegrated arkose conglomerates; (*b*) yellow, micaceous, feldspathic sandstone; (*c*) brown-red sandstones or freestones, and (*d*) soft red argillaceous shales. These are interbedded and many times repeated, a fact which indicates rapidly changing and recurrent conditions of sedimentation. Although there are many layers of red shale in this subdivision the characteristic beds are the arkose conglomerates and sandstones, the latter of which afford valuable building stones.

In addition to the cross-bedded structure which often pre-

the State Geologist of New Jersey for 1896, pp. 25 *et seq.;* Annual Report of the State Geologist of New Jersey for 1897, pp. 23 *et seq.:* JOUR. GEOL., Vol. V, pp. 541–562. A detailed account of the New York area will be published in the Annual Report of the State Geologist of New York, and a briefer summary in the Annual Report of the State Geologist of New Jersey for 1898.

vails in the sandstones, ripple-marks, mud-cracks and impressions of rain-drops occur. The rapid alternation from conglomerates to shales and *vice versa*, the changes in composition in individual beds, the cross-bedding, ripple-marks, etc., all indicate very

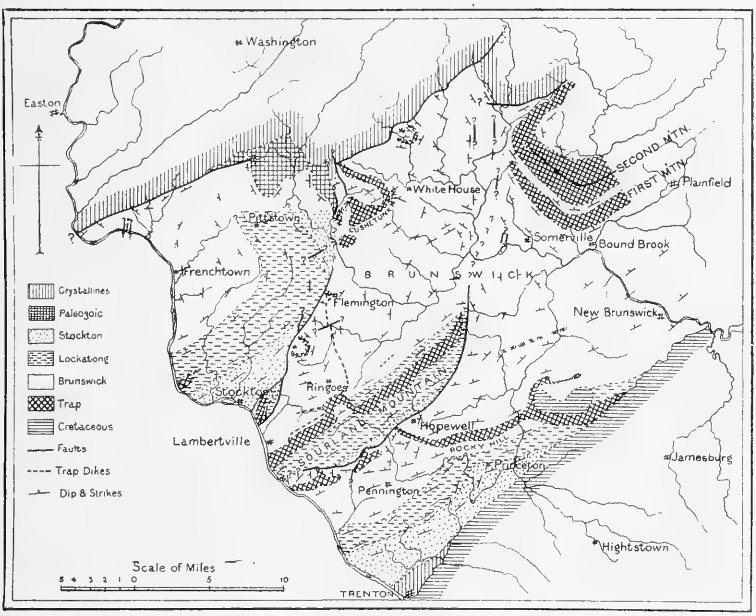

FIG. 2.—Subdivisions of the Newark rocks in Western New Jersey.

clearly that these beds were deposited in shallow water in close proximity to the shore. The bulk of the material of which they are composed was derived from the crystalline rocks on the south and southwest, but where they were found to rest upon Silurian shales, limestones and quartzites, as was the case along the northwestern border north of Flemington, material from these formations has determined their local character. The regions of the Stockton beds form gently rolling lowlands.

The Lockatong group.—These rocks overlie the Stockton beds conformably. They consist of (*a*) carbonaceous shales, which split readily along the bedding planes into thin laminæ, but have no true slaty cleavage; (*b*) hard, massive, black and bluish-

purple argillites; (*c*) dark gray and green flagstones; (*d*) dark red shales approaching a flagstone; (*e*) and occasional thin layers of highly calcareous shales. There are all gradations between these somewhat distinct types, so that the varieties of individual beds are almost countless. Both ripple-marks and mud-cracks occur at all horizons, showing that shallow water conditions prevailed throughout the time of their deposition. On the other hand, the absence of strong currents or violent shore action is indicated by the extreme fineness of the material.

The Lockatong beds are ridge makers, owing to their superior hardness and consequent resistance to the agents of degradation. In this particular they are surpassed only by the trap rocks. Sourland Mountain is composed largely of these rocks, although its backbone is formed by the outcropping edge of a trap sill. The high plateau in Hunterdon county, between Flemington and Frenchtown, which rises 300 to 500 feet above the adjoining region, is due also in large measure to the comparative indestructibility of these hard argillites and flags. They give rise to a rather heavy wet clay soil, often swampy unless artificially drained. The surface is quite thickly strewn with slabs of argillite and flagstone and on the steeper slopes rock outcrops are generally abundant.

The Brunswick beds.— In general this group consists of a monotonous succession of very soft argillaceous red shales which crumble readily to minute fragments, or split into thin flakes. Much of it is porous, the minute, irregular-shaped cavities being often partially filled with a calcareous powder. Calcite veins and crystals are common in some layers. Locally lenticular masses of green shale occur in the red. In size these range up to a foot or two in diameter, and vary in shape from nearly spherical to lenticular masses, narrowing down to thin sheets along cracks. They are undoubtedly due to chemical changes resulting in the leaching of the shale.

Although the majority of this series are soft red shales, there are some hard layers, chiefly near the base, and occasional beds of fine-grained sandstone and flagstones, some of which

afford valuable building material. Massive conglomerates along the northwestern border are in part the shoreward correlatives of the red shales.

Evidence that the shales were deposited in shallow water is abundant. Ripple-marks, mud-cracks and rain-drop impressions occur at many horizons. In some quarries imprints of leaves, of tree stems, or the stems themselves are frequently found. The numerous reptile tracks which have made the Newark beds famous occur chiefly in this subdivision. Typical exposures occur along the Raritan River, particularly near New Brunswick. The Brunswick beds are easily disintegrated and the fineness of the residuary material renders its transportation easy. Consequently the region underlain by these shales forms a lowland of faint relief, much of which has an elevation of only 100 to 200 feet above sea level. This plain is best developed in the drainage basin of the Raritan River, from New Brunswick northwestward to Flemington and White House. These rocks form also the western and lower part of the Hunterdon plateau in the vicinity of Frenchtown.

Owing to two great faults these three subdivisions each occur in three belts in the western part of New Jersey as shown by Fig. 2.

Lithological changes in these types. — Important lithological changes occur in all these beds as they are traced along their strike. As the northwestern border of the formation is approached, near Pittstown, the subdivisions lose their distinctive characteristics and merge along the strike into coarse sandstones and massive conglomerates. This change is most striking in the case of the Brunswick and the Lockatong groups, where red shales or black argillites change to sandstones and then into conglomerates, the pebbles of which are frequently six or eight inches in diameter. Under these conditions it is impossible to differentiate and limit these groups in this part of the field. Before considering these border conglomerates more fully, other modifications in the beds will be noted.

Important changes are found to occur as the beds are traced

along the strike northeastward into New York. The Stockton beds disappear beneath the later deposits a few miles east of Princeton. But owing to a slight change of strike they come to the surface again on both sides of the Palisades from Hoboken

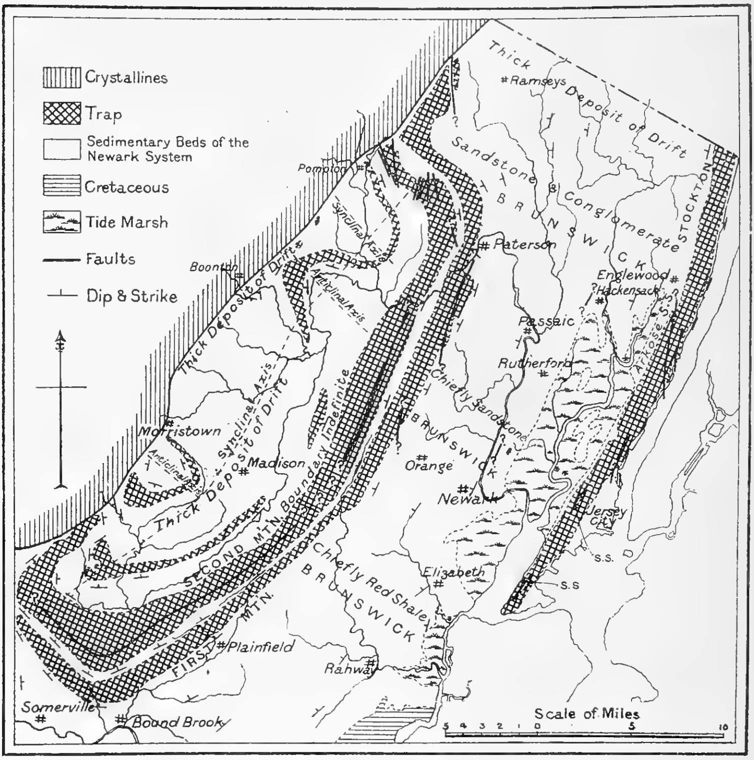

FIG. 3.—Newark rocks of Eastern New Jersey.

northward (Fig. 3). They are exposed in many places along the foot of the Palisades near the water's edge, and in a few localities where the glacial drift is thin, the typical arkose sandstone has been found on the west side of the Palisades. These rocks are correlated with those of the Trenton area for the following reasons. Lithologically, they are almost exactly identical; in both there are coarse arkose sandstones locally con-

glomeratic; in both, red shales and reddish-brown free-stones, and in both, these layers are several times repeated. Second, both occupy the same position stratigraphically. Near Trenton they are found resting upon the older crystalline rocks. In Jersey City wells bored near the water front strike gneiss and schist. At Stevens Point, Hoboken, the crystalline rocks outcrop, and, as is well known, they underlie the whole of Manhattan Island, just across the river. A little over half a mile back from the water front, in Jersey City and Hoboken, wells, which penetrate the glacial drift, reach sandstone and shale, some beds of the former being unmistakably coarse arkose. Third, minute crustaceans (*Estheria ovata*) have been found[1] in the shale beds at Weehawken and Shady Side along the Hudson River, and again in similar relations in the quarries near Trenton. Owing to the intrusion of the Palisade trap sheet some members of the group have been metamorphosed into hard, black and greenish flinty rocks, called hornfels by some German petrographers. Their occurrence, however, is limited to the neighborhood of the trap, and their presence in nowise affects the correlation of these beds with those near Trenton.

The Stockton beds certainly persist into New York, but the typical coarse arkose sandstone beds apparently thin out, and north of Nyack the group cannot be identified with any degree of certainty. The trend of the strata apparently carries the beds of this subdivision beneath the Hudson River.

Northeast of Princeton the outcrop of the typical Lockatong group grows narrower and the thickness less. Either the rate of deposition was slower to the northeast during the time represented by the Lockatong beds elsewhere, and therefore they are thinner here, or else, the rate of deposition being the same as elsewhere, the conditions favoring the deposition of black argillite and shale did not last so long to the northeast of Princeton as nearer the Delaware. A few miles northeast of Princeton the Lockatong beds also are covered by the Cretaceous deposits, but they have been traced by borings as far as

[1] NASON, Annual Report of the State Geologist of New Jersey, 1888, pp. 29–33.

the Raritan River. They do not, however, appear in the region west of the Palisades and north of Newark (Fig. 3). In the region in which they would be expected to occur the broad Newark and Hackensack meadows are found. The Lockatong beds are always ridge makers, rising above the level of the rocks on either side, and therefore it is impossible to suppose that they underlie these great tide-water meadows. There can be no doubt but that the argillites do not exist in the northern region. It is hardly probable that sedimentation ceased entirely in this northern area while the argillites were being deposited in the southwest, since there is no evidence of such oscillations of sea level or of unconformity. It seems more probable that the conditions favoring their formation did not prevail in the northern part of the basin; that here the red shales and sandstones were deposited contemporaneously with the argillites and flagstones to the southwest, and that, could we trace the latter from the point near Princeton, where they disappear beneath the Pensauken and Cretaceous deposits, we would find all the steps in their transition to the soft red shales.

The Brunswick beds likewise change in texture towards the northeast. They are predominantly soft argillaceous shales from the Delaware River as far as Elizabeth. In some layers an increase in coarseness is noticeable, which continues northeastward along the strike, until in the vicinity of Newark and Orange the beds are chiefly sandstones. Many of these beds resemble the brownstones of the Stockton series, so closely in fact that hand specimens can be distinguished with difficulty, if at all, from much of the sandstone at Trenton and Stockton. But their stratigraphical position in the Newark series seems to be far above that of the Stockton beds. The facts on which this conclusion is based are as follows. The trap sheet forming First Mountain is extrusive in origin. That is, it is an overflow sheet,[1] and, therefore, its base is conformable to the

[1] This might not be the case had the lava flowed over an eroded land surface, but evidence will be given below to prove that the lava flow was subaqueous, and therefore contemporaneous with the deposition of the adjoining shales. Its base therefore represents a constant horizon.

bedding of the sandstones, and represents a constant horizon. This being the case it gives us a reliable datum line. The position of the sandstones near Newark and vicinity in reference to the trap agrees with that of the Brunswick *shales* further south, and not with that of the Stockton sandstones. Second, they are too far removed from the base of the series, which follows the Hudson River, to be classed with the Stockton beds. Thirdly, when traced southward along the strike as closely as possible, considering the limited number of outcrops, they appear to grade into soft argillaceous shales.

Still further north layers of conglomerate appear interstratified with the sandstones and shales. In addition to well-marked beds of conglomerate, many layers of the sandstone contain pebbles scattered through them. The pebbles are chiefly of quartzite or sandstone, quartz, slate, limestone, feldspar, and rarely of flint. Not a single gneissic or granitic pebble was found, although careful search was made for them. The coarse sandstone and conglomerates, with some shale beds, continue through Bergen county, N. J., and Rockland county, N. Y. Since this phase of the Brunswick group is more resistant than the argillaceous shales in the Raritan basin, the topography is quite different. Where the Brunswick beds are soft red shales, the surface is a gently-rolling lowland, having an average elevation of from 100 to 200 feet above tide. With the appearance of the coarser and more resistant beds the general elevation becomes greater, and in place of the gently-rolling lowland, we find a series of ridges and valleys following very closely the trend of the beds. Toward the New York state line the higher of these sandstone ridges attain elevations of 450 to 625 feet above tide, the local relief being from 200 to 300 feet.

Owing to the disappearance of the Lockatong beds as a group possessing distinctive features, and the change in the Brunswick group due to the appearance of thick beds of brown sandstone and of coarse conglomerate, it is not practicable to differentiate on a map these groups as sharply as could be done

in the western part of the area. Their general distribution is indicated on the maps shown in Figs. 3 and 4.

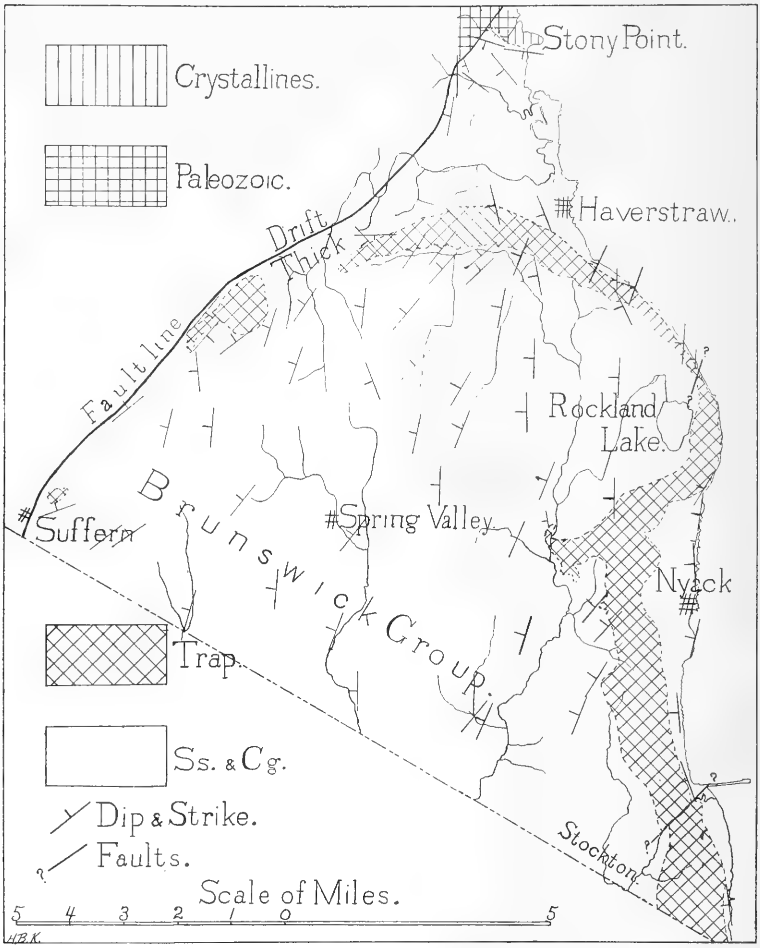

FIG. 4.— Maps of the Newark Series in Rockland County, New York.

Border conglomerates.—Beds of coarse conglomerate occur at a number of points along the northwestern border. Some of these are composed chiefly of quartzite, others of limestone, and in one case of gneissic and granitic material. The quartzite

conglomerate contains a few pebbles of limestone, shale, and gneiss, but almost the entire mass of the rock is made up of quartzite or sandstone pebbles, which are well rounded and frequently six or eight inches in diameter. They are best exposed in the "pebble bluffs" along the Delaware River about five miles above Frenchtown. The conglomerates are interstratified with sandstones and shales, forming lenticular beds, which thin out within a few rods, to be replaced by beds of a different texture. This alternation and rapid change betoken shore conditions. The quartzite conglomerate is also well developed (*a*) in "the Barrens" northwest of Pittstown, (*b*) south of Clinton, (*c*) four miles north of Peapack, where there is an outlier called Mount Paul, (*d*) south of Morristown, and (*e*) south of Pompton Lake.

The calcareous conglomerate is in appearance almost the exact counterpart of the famous "Potomac marble" quarried at Point of Rocks, Maryland.[1] The limestone pebbles are usually bluish or gray, sometimes reddish, set in a red mud matrix, so that the rock has a variegated appearance. The average diameter of the larger constituents is six or eight inches, but bowlders five feet in diameter have been seen, and at a quarry two and a half miles northeast of Suffern, N. Y., bowlders twelve feet in diameter are reported to occur. The larger fragments are generally rounded, but the majority of the smaller are sharp-cornered or at most subangular. Compared with the pebbles in the quartzite conglomerate, the limestone pebbles are but little worn, a fact of some significance in connection with the origin and source of the materials, since with equal transportation the softer limestones must have been most worn. In many localities this conglomerate is so pure a limestone that it is quarried and burnt for lime for local use.

Three small areas of this conglomerate occur northwest of Pittstown between hills of the quartzite conglomerate. A much larger area lies along the border northwest of White House. In New York state it occurs (*a*) two to three miles northeast of Suffern, (*b*) near Ladentown, and (*c*) south of Stony Point.

[1] Geological Survey of Maryland, Vol. II, pp. 187–193.

Not uncommonly the most careful search failed to reveal a single gneissic or granitic pebble in the border conglomerates, even although the adjoining rocks were of this character. But east of Boonton a conglomerate composed chiefly of crystalline pebbles extends for two or three miles along the border.

Relations of these conglomerates to the older rocks.—The relations of these conglomerates to the older rocks along the border are significant. In some cases the calcareous conglomerates adjoin small areas of Paleozoic limestone, from which the materials may have been and probably were derived. In other cases, and *this is true of the largest areas*, the calcareous conglomerates abut against the gneissic rocks, and for much of the distance it is certain that no limestone occurs between the gneiss and conglomerate, at least not at the surface horizon. Crystalline pebbles, however, are comparatively rare in the conglomerate. Substantially the same conditions prevail in the case of the quartzite conglomerate. For the most part it adjoins the gneiss, but gneissic pebbles in it are rare. The known areas of quartzite along the border are small, and in general not near the massive conglomerate beds. Lithologically, moreover, they are unlike the bulk of the quartzite pebbles.

It is evident that along the greater part of this border the beds of the Newark series were not derived from the older rocks which now immediately adjoin them. Shore currents doubtless transported more or less material somewhat widely, and yet they do not afford us the complete explanation for these facts. The northwestern border is for the most part marked by faults. Here the dissimilarity of constitution is the most marked. Where the border is not faulted and the newer rocks rest undisturbed upon the eroded edges of the older beds, they are composed of fragments derived from them plus a small contribution by shore currents. Allowance can be made for the work of the currents, but the widespread dissimilarity of constitution is due chiefly to the faulting which has occurred. The waves of the sea in which the Newark beds were deposited did not on the northwest border in general beat against the rocks which now adjoin this area.

The relation of the conglomerates to the shales is also significant. They do not form a single horizon which may be used in interpreting the structure. Instead, they grade either into argillaceous shales, or black argillites, or arkose sandstones. Time and again the pebbly layers were seen to appear in the shales and to increase in thickness and numbers until they became massive conglomerates. This is true both of the calcareous and quartzite conglomerates, and probably also for the gneiss conglomerate, but owing to the glacial deposits its relation to the shales could not be determined.

The trap rocks.—The trap rocks of the Newark beds in New Jersey and New York have been described more or less in detail by several geologists,[1] and it has been demonstrated that overflow sheets, intrusive sills, plugs, and dikes occur. Owing to its superior hardness, the trap rock has better resisted erosion than the sedimentary beds, and consequently forms more or less well-marked elevations. In the case of narrow dikes, the elevation is slight and readily overlooked, but the greater masses form hills or ridges rising not infrequently 300, 400, or even 500 feet above their surroundings. The structural relations of the trap masses are among the most interesting questions connected with the Newark series, but only general conclusions can be given here.[2] The most important of the overflow sheets are the three concentric ridges forming the Watchung Mountains, Fig. 3. These sheets are to all appearances strictly conformable, both to the underlying and to the overlying shales. Nowhere is there any indication that the trap breaks across the sandstone or shale layers. Wherever the basal contact is exposed, and exposures several hundred feet in extent are known, the trap is seen to follow exactly the bedding plane of the shales.

Moreover, the extensive metamorphism of the associated sedimentary beds, a marked feature in the case of all the intru-

[1] Chiefly COOK, RUSSELL, DAVIS, DARTON, IDDINGS, KÜMMEL.

[2] Detailed descriptions are given by N. H. DARTON, U. S. Geological Survey, Bulletin No. 67, and by the author in the Annual Report of the State Geologist of New Jersey for 1897, pp. 58–100.

sive sheets, is entirely absent. Locally, the shale is slightly altered for a few inches beneath the trap, but even this is not always the case. When this is compared with the intense alteration which has affected the shales beneath the Palisades, an intrusive sill, for a distance of over 100 feet, the difference between the sheets is emphasized.

Upper contacts have not been observed in many cases, but the upper surface of these sheets is frequently vesicular, amygdaloidal, and scoriaceous. Locally, a thin layer of waterworn trap particles, intermixed with red mud occurs between the vesicular trap and the unaltered typical red shales, or the vesicles are filled with the red mud. The overlying shales conform to the slightly irregular, ropy surface of the trap. In frequent exposures the rolling-flow structure, named by the Hawaiian Islanders *Pa-hoe-hoe*, is visible. Nowhere have any tongues of lava been found extending from the main sheet into the neighboring shales.

In texture there is a marked difference between the overflow sheets and the intrusive sills. Not only is the trap vesicular and even scoriaceous at many points on the upper surface, but it is uniformly of much finer grain than that of the Palisades and similar ridges. Microscopic examination of fragments from the upper surface shows that volcanic glass occurs to some extent. The conclusions drawn from the texture are that these masses cooled much more rapidly than did the Palisade trap. Locally, vesicular and scoriaceous layers occur next to the under-shales, beneath dense, fine-grained trap. Generally in such localities the rolling-flow structure is clearly marked. The inference from these facts is that as the lava flowed onward the partially cooled vesicular slag-like and broken upper surface was rolled over to the under side of the flow, or in other cases, after a clinker-strewn crust had formed on the top and front of the sheet, the molten lava broke forth from within and flowed over and around the scoriaceous fragments, and on hardening bound them firmly together. Occasionally the red shale rises into the base of the trap, as if the great pressure and flowing motion of the molten

lava had forced upward the soft mud on the sea bottom, or as if the steam generated by the intense heat had made the wet mud to froth up between the trap clinkers. There can be no doubt as to the extrusive origin of these sheets.

The crescent-shaped ridges near Morristown, north of White House (near Germantown) and southwest of Flemington (near Sand Brook), are also overflow sheets.

Intrusive sills.—The Palisades of the Hudson, the Rocky Hill sheet north of Princeton, the Sourland Mountain sheet near Lambertville, and Cushetunk Mountain near White House, are the largest and most prominent of the intrusive sheets. Their position, size, and the shape of their outcrop are indicated on the accompanying maps. In addition to these, which are demonstrably sills or sheets, there are more irregularly shaped masses northwest of Pennington, near Stockton, and at Point Pleasant (west of Stockton), (Fig. 2), the precise relations of which to the inclosing beds are not clearly revealed. They are beyond all doubt intrusive masses, but it is questionable whether they are strictly sheets. In the absence of positive knowledge as to their relations with the sedimentary beds, I prefer to speak of them simply as intrusive masses.

The evidence of the intrusive origin of all these masses, sills and others, is as follows. Dikes radiate from the upper part of the sills and penetrate the overlying shales for distances up to seven miles, as measured on the surface. The sills are locally unconformable to the inclosing strata, although in general they extend for long distances parallel to their strike. The Sourland Mountain sill makes two sharp bends, by which it changes its horizon several hundred feet. The Rocky Hill sheet crosses the shales obliquely for a total of several thousand feet, and about twenty-five localities are known along the Hudson River where the Palisade sheet can be seen to cut across the shales and sandstones. In New Jersey the Palisade sheet follows closely the strike of the shales, although frequently changing its horizon a few feet. In New York, however, north of Nyack, the trend of the shales would carry it beneath the Hud-

son River, were it not that it ascends by irregular steps to higher horizons. West of Haverstraw it trends nearly at right angles to the strata, and is more like a dike than an intrusive sheet. A small area near Ladentown, which may be the western extension of the Palisades, presents some characteristics of an overflow sheet, indicating that possibly the trap here reached the surface. The adjacent sediments have often been greatly metamorphosed. So intense has been this alteration that at distances, often of 100 feet the rocks are as completely "baked" as those immediately adjoining the trap. Measured along the surface, traces of metamorphism are frequently found one foot from the nearest trap outcrop. The complete absence of scoriaceous rock, of amygdules, of the vesicular, or the rolling-flow structure, is negative evidence of their intrusive origin which must not be neglected. Moreover, masses of shale and sandstone have been imbedded in the trap near both the under and upper surfaces, and the trap itself shows evidence in its texture of having cooled more slowly (and therefore presumably at greater depths) than the overflow sheets.

Plugs.—Round Mountain, a circular mass of trap, south of Cushetunk Mountain, suggests by its shape, that it is an irruptive plug or stock, but in the absence of positive evidence as to its relations to the surrounding metamorphosed shales, no final statement is warranted.

Dikes.—The positions of the principal dikes are represented on the accompanying maps. A few others are known, but are too small to show on a map of this scale. Locally the adjoining shales are slightly metamorphosed.

The age of the trap rock.—The overflow sheets are contemporaneous with the beds between which they lie, *i. e.*, the upper third of the Brunswick shales.

The intrusive masses extend, for the most part, well up into the Brunswick shales, and are therefore younger than these. Moreover, so far as the evidence goes, they antedate the disturbances which closed the deposition of the Newark beds. There are good reasons for believing that many, perhaps all, of

the intrusive masses are younger than the extrusive sheets, although the evidence is not conclusive. From *a priori* considerations it may be suggested that the lava formed intrusive sheets after the formation became so thick that it could not readily rise to the surface; whereas, earlier in Newark time the lava was able to break through the thinner beds and overflow.

Metamorphosed shales.—The chief effect of the trap on the shales is the contact metamorphism which has been produced by the larger intrusive masses. The most marked macroscopical changes are (*a*) a greater or less induration, (*b*) change in color —red shales in general becoming purple and then a blue-black, streaked with gray or green near the trap, and (*c*) the development of secondary minerals, commonly epidote and tourmaline. The rock often has a banded or mottled appearance, due to the formation of lime-silicate hornfels. Of these three changes the third is the most significant. Mere induration or change of color does not necessarily signify "baking," but when all three occur together, and only in layers in close proximity to certain trap sheets, proved to be intrusive by their structural relations, the changes can be safely ascribed to the igneous rock. Many of the altered shales on weathering become a pale blue or ashy gray color, a tinge never taken by other layers.

Detailed microscopic study of the altered shales has been made by Messrs. Andreæ and Osann[1] from specimens collected at the base of the Palisades at Hoboken and Jersey City. Their results, which were published in Germany, are inaccessible to many readers in this country, and are therefore here briefly summarized. They group the metamorphosed rocks into four classes:

1. Normal slate hornfels, not distinguishable from hornfels formed by contact with intrusives which cooled at great depth.

2. Hornfels containing numerous tourmaline crystals.

[1] Tiefencontact an den intrusiven Diabasen von New Jersey. Separat-abdruck aus den Verhandlungen des Naturhist.-Med. Vereins. zu Heidelberg. *N. T. V.*, Bd. 1. Heft.

3. Metamorphosed arkose sandstone, distinguished by the formation of a fibrous green hornblende.

4. Lime-silicate hornfels (kalksilikat hornfelse).

The two first groups differ only in the presence or absence of tourmaline. They are very dense rocks, with a splinter-like cleavage and abound in biotite. Traces of the original stratification are preserved in the alternation of layers containing varying amounts of mica. The tourmaline always appears as a secondary mineral, in well-bounded black prisms up to three millimeters in length and one in width. They are without definite arrangement, the longitudinal axis being oblique to the stratification plane as frequently as it is parallel to it. Each of the tourmaline crystals is surrounded by a bright halo about half a millimeter in width, caused by the absence of biotite. This may be accounted for on the assumption that the iron and magnesia were consumed in the formation of the tourmaline. The biotite crystals have their tabular planes arranged parallel to the stratification planes.

Feldspar is the chief constituent of the tourmaline-bearing hornfels, and quartz is entirely wanting—a fact which indicates that the original sediment was very deficient in silica, but abounded in clayey materials.

From such rocks, presenting clearly a crystalline structure, a transition may be found to very dense masses in which, even when highly magnified, no constituent parts, save biotite, can be recognized.

The lime-silicate hornfels is bright gray to green-gray in color, dense and hard, and discloses, under the microscope, an irregular aggregate of very small grains, with strong double refraction, whose nature can be determined only from the larger grains. The minerals common to rocks of this variety occur; a colorless pyroxene, closely related to diopside; green hornblende; colorless tremolite in fibrous and radiating aggregates; garnet; vesuvian; epidote; while feldspar occurs commonly in diminished quantity. This rock frequently exhibits an alternation of bright and dark layers, in the former of which diopside usually prevails; in the latter green hornblende and biotite.

Solitary grains and crystals of titanite occur and frequent masses of calcite were observed. The lime-silicate hornfels effervesces with acid. Their occurrence here indicates a deep-seated origin for the Palisade sill.

The association of the slate hornfels and the lime-silicate hornfels is extremely interesting. The former makes up the main mass of the altered beds. The lime-silicate hornfels forms in most cases small layers in the slate hornfels, the thickness of the former often being no greater than that of a sheet of paper. These layers are parallel to each other and to the original stratification of the shales. Frequently they form small elliptical masses, joining each other like a string of pearls in the stratification plane. From this it is but a step to rocks in which the lime-silicate hornfels form only roundish eyes and knots in the hard, black slate, the "incipient segregation," which gives the rock a mottled appearance. In still other cases the lime-silicate hornfels traverses the darker hornfels in veins and bands at various angles to the stratification. Before metamorphism these were probably veins of calcite, which, together with the surrounding shales were altered on the intrusion of the trap.

In all these various relations the boundaries of these two rocks, of such different chemical composition, are sharply marked, both to the naked eye and microscopically. This is strong evidence that during the metamorphism these rocks were not molten, but that the changes occurred in solid, or at most, very slightly plastic beds. The authors conclude that the beds were originally argillaceous shales, locally strongly calcareous and traversed by veins of calcite and interbedded with layers of arkose sandstone. They find in the contact phenomena strong evidence that the trap was intrusive and cooled at great depths.

Metamorphosed shale, in every respect identical with these rocks, so far as macroscopical examination can determine, occurs along the Rocky Hill ridge, and is well shown along the canal near Rocky Hill village. Epidote and tourmaline-bearing shales occur on both sides of the Sourland Mountain trap, and are well exposed at Lambertville, where many of the features

noted by Andreæ and Osann can be seen. Fragments of altered shale can be found on the surface near the other intrusive trap masses, but there are no extensive exposures of the rock in place. Along the Palisade ridge the metamorphism is less pronounced near its northern end in New York, and not infrequently beds in close proximity to the trap here show no signs of alteration. Apparently, as the molten rock approached the surface, its effect upon the adjacent beds was diminished.

STRUCTURE

Folds.—The general structure is that of a faulted monocline the beds of which trend N. 20° to 50° E., and dip 10° to 15° to the northwestward. As a result of this, the layers to the northwest, save where faulting has occurred, are above, and therefore younger than the layers on the southeastern side. When examined more in detail, the structure is seen to depart locally from a monocline. Several broad, gentle flexures occur, in addition to a few sharply marked folds in the vicinity of the intrusive traps and greater fault lines. A good example of the former is seen in the shales of the Hunterdon plateau, where the beds are so inclined that their outcropping edges describe a great curve, parallel on the east, and southeast to the escarpment of the plateau. The structure is a shallow syncline, whose axis is inclined northwestward. Low folds occur in the valley of the Raritan, particularly in the region north of Somerville. From New Brunswick to Bound Brook the dip is quite uniformly to the northwestward, averaging ten degrees, but further to the west the monocline is interrupted by gentle flexures and swells which are difficult to trace because of the absence of individuality in the layers. The broad outcrop of the Brunswick shales in the Raritan valley is due in large part to these low folds.

More definite folds, all synclines, occur (*a*) near the Sand Brook trap sheet, southwest of Flemington, (*b*) the New Germantown trap sheet, and (*c*) the Watchung traps, whose great crescentic curves are due to the synclinal structure of the inclosing shales. Several examples of sharp folds occur near Glen-

more, southwest of Hopewell, and not far from the end of Rocky Hill. Other instances were noted near the faults.

In the area shown in Fig. 2, the Stockton and Lockatong beds are the more constant in dip and strike, so that the monoclinal structure is most marked in these belts. The Brunswick shales are characterized by shallow folds, some of them covering an area of several square miles. These, combined with a fortunate arrangement of faults, have greatly increased the area of red shale outcrop, and so permitted the formation of the broad, rolling lowland, so characteristic of the greater part of the Newark system.

Within the area shown in Fig. 3, the extrusive trap sheets are excellent guides in interpreting the structure, once their conformity to the shales has been completely demonstrated. The curved outline of the Watchung Mountains is due to a gentle synclinal fold, the westward side of which has been cut off by a fault along the highland border of the formation. The highest beds of the Newark series are those along the axis of this syncline. Between the Watchung Mountains and the Hudson River the monoclinal structure prevails. This is also true of the Newark beds of the New York area.

Faults.— About seventy-five faults are known to occur, and two of them, the Flemington and Hopewell faults, are of great magnitude and extent, causing a repetition of all three divisions of the Newark beds and involving dislocations equivalent to a vertical movement of one half the entire thickness of the series, perhaps 6000 or 7000 feet. Faults of such magnitude must extend downward beyond the limits of the Newark rocks, and involve the foundations on which they rest. Proofs of the faulting are found (*a*) in the repetition of the strata, (*b*) crushed and contorted strata, slicken-sided surfaces or overthrown dips at every exposure along or near the fault line, (*c*) diversity of structure on opposite sides of the fractures, (*d*) contrasts in the topography, and (*e*) the termination of ridges at the line of disturbance.

The northwestern border is formed in part by a series of

faults. Elsewhere the Newark beds rest upon the eroded edges of the older rocks. The faulted border is comparatively straight; the normal border is somewhat crooked. Along the former the shales dip in various directions in respect to the older rocks; along the latter they follow the trend of the contact and dip away from the older beds. In the one case Newark beds of very different horizons adjoin the border; in the latter they are basal beds. Along the faulted portion the Newark beds were not derived from the immediately adjoining older rocks; along the normal contact material from the adjacent old formations has entered largely into the newer beds.

The trap ridges, notably the Palisades and the first and second of the Watchung ridges, are cut by a number of faults which cross them obliquely. Second Mountain, moreover, is cut by a curving fault which follows the ridge for many miles, producing a double crest and revealing a strip of shale in the valley between. The throws of the faults rarely exceed 200 feet, save in the case of this longitudinal fracture where it is probably 700 feet or over. Owing to the monotonously uniform character of so many of the sedimentary beds, all estimates of the amount of throw are generally unreliable. Faulting is more frequent in the Brunswick and Stockton beds than in the Lockatong group, but the total number observed in all three subdivisions is hardly more than that found in the trap areas. There is good reason for believing that many faults which traverse the sedimentary beds have not been discovered, and perhaps never will be, with the present methods of geological research. With but few exceptions, all the known faults are reverse faults.

The thickness of the sedimentary beds.—In my earlier papers the following estimate of the maximum thickness of these beds was made.

Stockton, - - - -	4,700 feet.
Lockatong, - - - -	3,600 "
Brunswick, - - - -	12,000 "
	20,300 "

At that time it was felt that not all these estimates were

equally reliable. Six sections were made across the Lockatong beds with the following results: Across the belt on the Hunterdon plateau, 3540 feet, 3450 feet, 3500 feet; across the Sourland Mountain area, 3600 feet, 3650, 3660 feet. The sweeping curve of this belt in the Hunterdon area, its uniform width, and the possibility of tracing certain subordinate but well-marked layers continuously along the strike preclude the idea that any great part of its apparent thickness is due to repetition by faulting. Furthermore, the fact that the beds on the Sourland plateau agree in thickness so closely with the same beds on the Hunterdon plateau is further reason for believing that the figures here given represent very closely the actual thickness. To suppose otherwise is to assume that these two separate areas are each traversed by faults, whose throw, by a remarkable coincidence, is almost exactly the same, but of which no traces have been discovered by areal work of the most detailed character.

The thickness of the Lockatong beds, near Ewingville and Princeton, seems to be only half of that in the other two regions, *i. e.*, 1700 to 1800 feet. The same relative thinness was observed in the Stockton beds, near Trenton, as compared with those further north. The explanation of this may lie in the fact that the beds of the former belt are nearer the old shore line than the others. Stratified deposits have the form of an unsymmetrical lens which thins out very rapidly shoreward and very gradually seaward. It is to be expected, therefore, that the thickness of this belt, which is nearest the old shore, would be somewhat less than that of the others. The weight of evidence indicates that in the deeper parts of the estuary the Lockatong beds were 3500 or 3600 feet thick.

The estimates for the Stockton and Brunswick beds are more uncertain. In favor of the estimates given above these facts may be urged. West of Ringoes the Brunswick shales form a syncline whose axis plunges northwest. Between 6000 and 7000 feet of shales are involved in this fold. It is improbable that a fault could follow the curving strike so as to repeat the

beds the same amount on both sides of the fold. Furthermore, a narrow trap dike was traced uninterruptedly from the back of Sourland Mountain, near Rocktown, to Copper Hill, a distance of five miles. The dike crosses the strike at an angle of forty-five degrees, and the thickness of the shales thus traversed is between 6000 and 7000 feet. There are reasons for believing that the trap was intruded before the tilting and faulting. If these reasons are valid the continuity of the dike is proof that the shales traversed by it are not cut by faults along the strike Since such great thicknesses prevail in these beds, which are only a part of the whole, there is some reason for believing that the entire thickness of the Brunswick shales is near 12,000 feet.

On the other hand the disparity in the number of known faults in the trap areas and in the sandstone and shale areas indicates that there are probably more faults in the sedimentary beds than have been discovered. The apparent thickness of the Palisades and the two Watchung ridges is from one half to one third greater than the actual thickness, the increase being due to the faults. If the same proportions hold for the Stockton and Brunswick shales the figures given above will be somewhat reduced. The revised estimate, therefore, is as follows:

Stockton, - - -	2,300	to	3,100	feet.
Lockatong, - - -	3,500	"	3,600	"
Brunswick, - - -	6,000	"	8,000	"
	11,800	"	14,700	"

There is so much uncertainty connected with all measurements where there are so many unknown elements that these estimates may be far from correct. It certainly can be claimed for them, however, that they rest upon a much larger basis of fact than many previous figures.

Of the trap sheets.—The thicknesses of the various trap sheets are not included in the above estimates.

The Palisades at Jersey City Heights have at least a thickness of 364 feet (well-boring), with a total thickness, including the amount removed by erosion, of 700 to 800 feet, according

to estimates made from the angle of dip and the width of outcrop. At Fort Lee a well penetrated the trap for 875 feet before reaching the underlying metamorphosed shale and the total thickness here is about 950 feet.

In New York the thickness varies considerably, judging by the width of outcrop. A thickness of considerably over 700 feet is known to occur north of Nyack, whereas north of Rockland Lake it probably does not exceed 300 feet.

The thickness of First Mountain at Paterson is estimated to be 600 to 675 feet; at Orange Valley about 670 feet; at Scotch Plains about 680 feet, and at Chimney Rock about 580 feet.

With the exception of the thickness at Scotch Plains these figures agree closely with those obtained for First Mountain by Darton along the same sections. At Scotch Plains the outcrop is narrower than elsewhere, but the dip of the inclosing shales is steeper and his estimate of 450 feet is probably too low.

The thickness of Second Mountain is apparently somewhat greater than that of First Mountain, but owing to the faults which traverse it, estimates are liable to error. Darton's figures range from 600 to 850 feet. My own estimates, based on the width of outcrop and the dip, range from 840 feet to 990 feet. At Caldwell the well at the Mount St. Dominic Academy penetrated the trap for nearly 800 feet, but some addition must be made for what has been removed from the crest of the ridge by erosion.

At Millington the thickness of the Long Hill trap sheet is about 300 feet. At Pompton a well drilled at the Norton house is reported to have passed through but seventy feet of trap before reaching sandstone. Hook Mountain, east of White Hall, has an apparent thickness of 400 feet or more.

The New Vernon trap-sheet has a thickness of about 250 feet, measured at the gorge near Green Village.

The outcrop of the New Germantown sheet is comparatively narrow, but the dip is steep and the thickness is estimated to be at least 400 feet.

The same thing is true of the Sand Brook sheet, the thickness of which is apparently not less than 425 feet.

Too little is known of the relations of the Sourland Mountain, Pennington Mountain, Bald Pate, and Rocky Hill traps to the inclosing shales to venture estimates of their thickness.

Deposition.— Most geologists hold the view that the Newark beds are estuarine deposits. Some, however, prefer to consider them lacustrine, believing that the scarcity of fossil remains renders improbable the supposition that the sea had free access to the basin. The fauna and flora preserved for us are meager, and do not settle the question decisively, the forms being such as might have existed either in an estuary or a salt lake. On the other hand, the distribution of the material implies well-marked currents such as the tides would produce in an estuary. For myself I prefer to believe that at the beginning of Newark time a broad, shallow estuary extended across the northern part of what is now New Jersey and into New York state. Whether the estuary was wider than the present area of the beds is impossible to say. Subsequent erosion has diminished their areal extent, whereas faulting, particularly in the western part of New Jersey, has increased it. Which of these factors has been the more effective is uncertain. Probably along the Delaware River section the gain by faulting has exceeded the loss in width by erosion. In the north this may not be the case.

The estuary was bordered on the northwest and southeast by areas of granite, gneiss, and schist, probably pre-Cambrian in age, with narrow belts of Paleozoic quartzite, limestone, and shale. The latter rocks formed in part the floor of the estuary, the foundation on which the Newark deposits were made. This is shown by the "island" of limestone and quartzite brought to the surface in Pennsylvania by the Flemington fault. For long periods previous to the formation of the estuary and the deposition of the Newark shales, the older rocks on which they now rest had been a land area and were deeply eroded. The proof of this is found in the absence from this region of all the later members of the Paleozoic series.

The constitution of the arkose sandstones near Trenton and beneath the Palisades shows that the sediment was derived chiefly from older crystallines on the southeast, but scattered limestone and sandstones pebbles derived from the southwest show that the currents had a northward trend along the southeastern border. Along the northwestern border, where it is not marked by faults, the material was evidently derived from the adjacent rocks on the northwest.

The constitution of the Newark beds points to the conclusion that in pre-Newark times the old land surface was deeply covered with residuary material, the product of long-continued subaërial decomposition. On the crystalline areas it was chiefly quartz and feldspar or kaolin. The limestone was buried beneath a mantle of clay. In both cases the residuary products had been formed chiefly by chemical agencies. The sandstone and quartzite rocks were less affected by chemical changes and relatively more by mechanical agencies. Their surface was, therefore, covered by subangular fragments, due chiefly to the rending action of frost and expansion and contraction with changes of temperature. The almost complete absence of gneissic pebbles with the presence of quartz, feldspar and partially disintegrated ferro-magnesian minerals in the conglomerates, sandstone or shales proves that the crystalline rocks must have been deeply covered with a mantle of residuary material, so that streams, although they had velocity enough to carry pebbles two or three inches in diameter, did not corrade the bed rock, but worked in the residuary material.

The bulk of the Newark beds is so great as to indicate that these residuary products must have been very thick. Their accumulation was aided by gentle slopes, hindered by steep declivities. Previous to the formation of the Newark beds the neighboring land surface seems to have been one of low relief, with gentle slopes, across which transportation was reduced to a minimum. In other words, the land surface was approaching the peneplain stage.[1] Had the land been high and the slopes

[1] Practically the same conclusion has been reached by Professor Davis in regard

steep the accumulation of these residuary materials in a thick mantle would seem to have been improbable. But the size of the materials handled by the streams during the Newark time indicates a velocity inconsistent with streams on a peneplain. It would seem, therefore, that with the beginning of the Newark deposition the land regained something of its former elevation. The rivers were able to carry from the crystalline areas pebbles of quartz or feldspar several inches in diameter and to handle quartzite cobbles ranging up to a foot in size.

The massive border conglomerates are probably not composed entirely of stream-transported material. Limestone bowlders poorly rounded and measuring four feet in diameter have been seen, and some twelve feet in diameter are reported to occur in the calcareous conglomerates. All the coarser border conglomerates were probably accumulated by the waves which beat against limestone and quartzite ledges. The scarcity of gneissic conglomerates indicates that the shores were not chiefly gneissic, as would be the case today were the Newark area to be submerged, but of limestone and quartzite. The faults along the northwest border have, for the most part, cut out these rocks, and brought the Newark beds against the crystallines.

That the sandstones and shales were accumulated in shallow water, is shown by the ripple marks, mud cracks, raindrop imprints, and footprints of reptiles and other vertebrates, which occur at all horizons. At no time apparently was the water of the estuary so deep that the outgoing tide did not expose broad areas of sand or mud. It follows from this that there must have been a progressive subsidence of the estuary during the deposition of these beds, since their thickness is to be measured by thousands of feet. The subsidence went on *pari passu* with the deposition of the sediments, since the shallow-water conditions prevailed continually. The progressive elevation of the adjoining land areas, shown by the material carried by the rivers, was

to the surface on which the Newark beds in Connecticut were deposited. His argument, however, was along an entirely different line of reasoning, being based upon the present topography.

complementary to this subsidence of the trough. If the subsidence were greater along one side of the trough than the other, the central axis must have shifted toward the side of greater depression, and the shore line on that side must have encroached upon the land. If this occurred to any marked degree during the later stages of sedimentation, the shore conglomerates of that time might rest upon the older rocks and so be basal conglomerates. At the same time they would be the correlatives of the topmost shales found further from shore. In this sense they would be the upper members of the series. This may have been the case locally along the northwestern border, and at the northern end of the estuary near Stony Point, but the evidence is far from conclusive on that point.

The lava flows.—Before the completion of the Newark sedimentation the quiet course of deposition was interrupted by great flows of lava. Whether the lava issued from a single vent or group of vents, or from a fissure is unknown. Certain it is, however, that the molten lava flowed over the soft mud in the bottom of the estuary. Locally the mud was forced up into cracks in the under side of the lava, or was thrown into low billows by the enormous pressure of the overflowing mass. The molten rock issuing forth into the water generated an enormous amount of steam, causing the mud to froth up and mingle with the scoriaceous lava. So, too, the more liquid lava flowed around and over the cooled and broken masses of clinkers, forming the ropy structure and the commingling of dense trap and breccia-like scoriæ sometimes seen in the Watchung trap sheets. Locally, perhaps somewhat generally, the lava flows were so thick as to rise above the sea level. In these cases the scoriaceous surface was readily eroded: the waterworn trap fragments were commingled with the red mud brought into the estuary by the rivers, and a layer of trap conglomerate or sandstone was formed. Such was the origin of the conglomerate in the back of the first Watchung sheet near Feltville. In other localities the vesicles on the upper surface of the lava were filled with the red mud as the lava flow was buried beneath the succeeding sediments. The three

Watchung trap sheets give us evidence of at least three periods of eruption separated by long intervals of quiet, during which the deposition of the shales went on as regularly as before. The intrusive sheets were probably formed after the overflow sheets but this has not been conclusively demonstrated. Since both the intrusive masses (save perhaps some dikes) and the extrusive sheets are cut by the faults, the volcanic phenomena preceded the faulting.

Professor Davis[1] has suggested that the disturbing force which ended the deposition, was probably "a long enduring and slow acting horizontal compression, exerted in an east and west, or southeast and northwest direction; and that the explanation of the tilted and faulted structure is to be found in the writhing and rising of the inclined layers of underlying gneiss and schist, as they were subjected to this horizontal compression." The foundation on which the Newark sediments rest would thus be faulted and canted, and "the overlying beds, unable to support themselves unbroken on this uneven foundation, settle down upon it as best they may." This explanation, offered to meet the conditions of the Newark beds of Connecticut, is fully applicable in its general features to the New York and New Jersey area.

HENRY B. KÜMMEL.

LEWIS INSTITUTE,
Chicago, January 1, 1899.

[1]DAVIS, U. S. Geological Survey. Seventh Annual Report, pp. 481–490.

THE PETROGRAPHICAL PROVINCE OF ESSEX COUNTY, MASS. II

Essexite.—The term essexite was first introduced by Sears who applied it to a group of basic rocks composed essentially of augite, hornblende, biotite, and plagioclase, with subordinate orthoclase, nepheline. or sodalite, which he regarded as the earliest crystallized and most basic portion of the nepheline-syenite magma of Salem Neck.[1] Rosenbusch[2] enlarges the mineral list to include olivine and apatite, and erects the essexite into a group of igneous rocks of the same order as the granites or diorites. He says of them that they are related to the gabbro family as the monzonites are to the normal syenites. They may therefore be considered as essentially basic monzonitic rocks, in which both lime-soda and alkali-feldspars and feldspathoids are present, and which are usually, if not always, derived from an alkali, and especially a soda-rich, magma. In Essex county they are confined to the immediate vicinity of Salem Neck, where they occur in large masses, accompanying and cut by the nepheline-syenite. They are quite distinct from this, and, so far as I know, few transition forms into this rock have been seen. On the other hand, they grade into the diorites of the neighborhood, so that in this direction it is difficult to draw a hard and fast line. These rocks have been described by Sears[3] and by Rosenbusch.[4]

They are dark gray or almost black rocks, of a granitic structure, and usually fine-grained, though varying to some extent in this respect. Biotite and feldspar phenocrysts and small round spots of augite and hornblende are seen in most specimens, but are not prominent. Specimens from one locality

[1] SEARS, Bull. Essex Inst. Vol., XXIII, 1891.

[2] ROSENBUSCH, Elem. d. Gesteinslehre, 1898, p. 171.

[3] SEARS, loc. cit.

[4] ROSENBUSCH, Mikr. Phys., p. 247, 1896.

on Salem Neck show a marked subschistose or platy structure. Rosenbusch has described the essexites of Salem Neck in considerable detail, and in general my observations agree with his descriptions. He has, however, included among the essexites proper certain rocks with what he calls a hyperitic structure, which, it seems to me, are not essexites proper, inasmuch as they contain neither alkali-feldspar nor nepheline, but constitute a dioritic facies of it.

In thin section the structure of the essexites proper is granitic, though the plagioclase shows a tendency to tabular development. The feldspar is mostly a plagioclase, showing clear twinning lamellæ, whose extinctions vary, but which correspond to compositions ranging from Ab_1An_1 to Ab_1An_2. Rosenbusch speaks of it as "hoch idiomorph," but for my specimens this is rather strong. It is certainly much more so in the hyperitic facies, while in the more normal essexites (such as the one analyzed), it is only rarely so. An alkali-feldspar is not uncommon, generally anhedral, and often microperthitic. This, and a microcline which is occasionally met with, are apparently rich in soda. Nepheline is fairly abundant, generally interstitial, but occasionally in well shaped crystals. I could not identify with certainty any of the sodalite seen by Sears.

Rosenbusch speaks of two remarkable peculiarities of the feldspars. The first consists of the presence, in gray dusty crystals or portions of crystals, of minute biotites, or hornblendes, about which there is a dust-free zone; the other is the presence of specks and veins of a colorless substance of low refrangibility, and either isotropic or faintly birefringent, which he thinks might be either glass or nepheline. Of the first of these I could find no example in my sections, and of the second only a little here and there which did not allow me to answer the question which Rosenbusch raises as to its nature.

In the typical essexite of Sears the most common ferromagnesian mineral is a deep green or greenish-brown, highly pleochroic hornblende, basal sections of which often show prismatic planes. This occurs scattered through the mass in

highly irregular grains and prisms, and also accompanying a colorless diopside, of which it seems to be an alteration product. The hornblende in this case is not rarely bluish-green, and apparently contains some soda. The pyroxene, which is not abundant, is a colorless diopside, usually in large crystals, and nearly always altered more or less to the green hornblende. It sometimes shows such brilliant polarization colors as to suggest olivine, but the fine straight cleavage lines and the oblique extinction prove it to be a monoclinic pyroxene. Small flakes and stout tables of a greenish yellow biotite are quite common. Titanite, often showing lozenge-shaped sections as well as in irregular grains, is abundant. Small grains of titaniferous magnetite are rare, and in nearly every case form the nucleus of titanite areas, which are apparently their alteration product. Long slender prisms of apatite are very abundant.

Specimens of the schistose variety vary a good deal. In a specimen given me by Mr. Sears the feldspars are largely in small anhedra, and the structure is microgranitic. Most of them are simple, perthites are not very common, twinning lamellæ rare. They have a brecciated structure and sometimes undulatory extinction, suggesting that the tendency to schistosity is due to pressure. Nepheline is present in considerable amount. Small irregular anhedra of a bright green aegirine-augite are scattered abundantly through the mass. A few large pale fawn-colored augites are seen, always more or less altered to a granular aegirite-augite. Small flakes of greenish-brown biotite and grains of titanite, often highly automorphic, are abundant, hornblende is almost wanting, and apatite scarce.

In other specimens the granitic groundmass is on a larger scale, the feldspars tabular and microperthite common, and interstitial nepheline abundant. An olive-green hornblende in beautifully automorphic crystals takes the place of the aegirite-augite, which is absent; large diopsides are rare, biotite almost wanting, titanite and apatite not abundant, and magnetite extremely scarce. No olivine was found by me in any of the varieties of the normal essexite.

The hyperitic variety is represented by two specimens from the southwestern part of Salem Neck, which only differ from Sears' type in being a little more coarsely crystalline, but much less so than the hyperitic diorites to be described later. The structure is somewhat ophitic, the feldspars being thick tabular, and the ferromagnesian minerals frequently xenomorphic towards them. At the same time these occupy bays and form inclusions in the feldspars, so that the crystallization must have been to a certain extent simultaneous. The chief peculiarity of the structure is the zonal growth of the biotite and hornblende about the pyroxene, olivine, and magnetite.

The feldspars are almost exclusively plagioclase, which is usually fresh, and with rather thick twinning lamellæ, whose extinction angles correspond to a basic labradorite, about $Ab_1 An_3$. Only a few grains of alkali-feldspar could be seen, and nothing which could be identified with nepheline. Olivine is present in some quantity, as rather large grains, usually automorphic though corroded. They are generally fresh, but sometimes partially serpentinized. A colorless or pale fawn-colored augite is present which shows high extinction angles. A reddish-brown barkevikitic hornblende is very abundant, showing the usual pleochroism; $\mathfrak{c}$=deep red-brown, $\mathfrak{b}$=deep red-brown, $\mathfrak{a}$=light brownish yellow, $\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$. It seldom forms independent individuals, but nearly always occurs as a border about the pyroxene and olivine. This border, which is usually of the nature of a reaction rim between the pyroxene or olivine and the feldspar, is highly irregular, often of great relative thickness, and in many cases almost entirely replaces the pyroxene. A brown biotite which is present in less amount also occasionally plays the same rôle. Magnetite and ilmenite grains are abundant, and about them is almost constantly found a hornblende rim when they are included in pyroxene, while, if they are included in feldspar, this is less common. Apatite is rare.

An analysis was made of a specimen from Salem Neck which was given me by Mr. Sears as representing his type. An analysis of a similar specimen, made by M. Dittrich for Professor Rosenbusch is given in II.

	I	II		I	II
SiO^2	46.99	47.94	BaO	none	....
TiO_2	2.92	0.20	Na_2O	6.35	5.63
Al_2O_3	17.94	17.44	K_2O	2.62	2.79
Fe_2O_3	2.56	6.84	H_2O	0.65	2.04
FeO	7.56	6.51	P_2O_5	0.94	1.04
MnO	trace	....			
MgO	3.22	2.07		99.60	99.92
CaO	7.85	7.47			

I. Essexite. Salem Neck. H. S. Washington anal.

II. Essexite. Salem Neck. M. Dittrich anal. (Rosenbusch. Elem. d. Gesteinslehre, 1898, p. 172. No. 1.)

The resemblance between the two analyses is close, the greatest differences being in ferric oxide, titanium oxide, and magnesia. It is possible that the low titanium oxide in Dittrich's analysis is due to the fact that it represents only the residue left after evaporation of the silica with hydrofluoric acid, while in mine, where the similar residue amounted to only 0.72 per cent., the titanium oxide was determined directly. The low silica and high lime and alkalies will be noticed, showing the basic monzonitic character of these rocks. Magnesia is rather lower than might be expected, a point which will be discussed later on.

Diorite.—This group is quite extensively represented in Essex county, the main occurrence being a long area with a general northeast-southwest trend in the western part, in Danvers, Topsfield, and Ipswich, a smaller area occurring about Salem and Marblehead and extending north into Beverly. From the large western area I have no specimens, all of mine coming from localities in the smaller areas about Salem and Marblehead. These rocks have been partially described by Sears[1] and are quite diversified in character.

Megascopically these are very dark, almost black, rocks, though a few are quite light, especially the main rock at Fort Sewall, Marblehead, which is a mottled light gray. This mass, by the way, is notable for the great number of "schlieren" and rounded masses of a dark, more basic diorite which it contains.

[1] SEARS, Bull. Essex. Inst., Vol. XXIII, 1891.

In structure they are always granitic, and in texture vary from rather fine to coarse-grain, the last looking like a typical diorite. The only minerals visible are white feldspars and black hornblende, biotite and augite.

Under the microscope it is seen that these rocks are essentially monzonitic in character, in Brögger's sense, orthoclase or an alkali-feldspar being almost invariably present along with the plagioclase, and that they vary from rather basic rocks rich in plagioclase and poor in orthoclase to more acid ones in which the orthoclase largely predominates over the plagioclase and where quartz also appears. The former closely approach the hyperitic varieties of the essexites, and, in fact, are only distinguished from these by their greater coarseness of grain and more dioritic appearance megascopically. The latter closely approach the akerites and perhaps should be described with them, but, on account of their intimate association with the dioritic rocks, and also because of their distinctly different megascopical character, they are placed here. Between these two extremes are found many transition types. The structure is always granitic or hypautomorphic, the dark minerals usually, but not always, having crystallized before the feldspars, the plagioclase generally before the orthoclase, and the quartz, if present, being always interstitial. None of the specimens are quite fresh, the best in this respect being some from near Collin's Cove, Salem Neck, which are hyperitic in structure.

The plagioclase, which has a tendency to stout tabular forms, is highly, and in many cases beautifully, twinned, according to the albite and pericline laws. It varies considerably in composition from an oligoclase, Ab_2An_1, to a basic labradorite, Ab_1An_3, the former being more abundant in the more acid orthoclase-rich varieties and the latter in the more basic, especially in specimens from Salem Neck. It is usually xenomorphic toward the ferromagnesian minerals, but not always, and is also met with as inclusions in the latter, so that it seems that, although the latter began to crystallize first, during a later stage the crystallization was simultaneous. Inclusions of augite,

magnetite and apatite are not rare. A quite common feature is the presence of numerous minute black rods which are square or long in section and are probably magnetite. In the specimen from Peach's Neck which was analyzed a reaction between augite and plagioclase has produced small flakes of brown biotite along the edges of the latter and extending into its substance. The alkali-feldspar is less automorphic than the plagioclase, and is often microperthitic. The quartz, which is abundant only in the main rock of Fort Sewall, is always interstitial and clear, with minute glass or liquid inclusions.

The ferromagnesian minerals vary much not only in amount but in kind. A colorless or almost colorless monoclinic pyroxene is most abundant. This corresponds in general to diopside, but in certain specimens, Peach's Neck, and in black "schlieren" at Fort Sewall, it has the habit of diallage, a parting parallel to (100) and (010) being prominent. The diopside shows high extinction angles and carries few inclusions. The diallage, which has a tendency to light brownish hues, is frequently crowded with minute magnetite (?) rods, which in sections parallel to (010) are arranged parallel with the direction of extinction, at an angle of 34° with the cleavage cracks. They also carry the small brown or opaque plates which are so frequent in the hypersthene of gabbros. These are not pleochroic and are apparently isotropic. In the hyperitic facies from Salem Neck the pyroxene is a light violet augite. The pyroxenes alter easily to uralite, brown hornblende, and biotite.

Primary hornblende is not abundant and is to be referred to two varieties. In the main rock of Fort Sewall and in specimens from Peach's Neck it is pale green or olive-green, not very pleochroic, and automorphic as well as fragmentary. In the basic hyperitic rocks of Salem Neck it is brown, much more highly pleochroic, and is apparently a barkevikite. Biotite, when primary, is greenish yellow or brown, the latter especially in the hyperitic forms. Secondary hornblende and biotite are extremely common, formed usually at the expense of the pyroxenes, and often in the form of reaction rims. A few crystals of

olivine entirely altered to serpentine were seen, but they are too rare to be of any importance. Magnetite is abundant in all the specimens, usually in large rounded grains. There seems to be a tendency for biotite to be produced from it when included in feldspar and hornblende when in augite, but this rule is not constant. Apatite is abundant in fair-sized stout crystals, more so in the basic than in the acid varieties.

It is evident that the rocks which are grouped under the heading of diorite are highly varied and that they represent transition forms from the essexites to the akerites. This is true at least for the area under examination; of the larger Danvers-Ipswich area I can say nothing. For the satisfactory study of these rocks several analyses will be necessary, but at present only one is available. The rock chosen for analysis was a specimen from the south side of Peach's Neck, a coarse-grained dark rock which shows under the microscope plagioclase, less orthoclase, no quartz, diopside, diallage, magnetite, apatite, and secondary hornblende and biotite. It is not quite fresh, but not altered enough to affect the result seriously.

SiO_2	51.82	CaO	8.59
TiO_2	2.15	Na_2O	3.44
Al_2O_3	17.06	K_2O	1.77
Fe_2O_3	1.97	H_2O (110°)	0.11
FeO	8.60	H_2O (ignit.)	0.20
MnO	none		
MgO	4.87		100.58

This is evidently the analysis of a diorite, though a basic one, the silica and alkalies being too high for a gabbro. It will be discussed later.

Quartz-augite-diorite.—The rocks which Sears calls by this name occupy a narrow area west of the rocks described in the preceding pages, which stretches through the county in a northeast-southwest direction from Andover to Newburyport and the New Hampshire line. Representing them I have only three specimens from Newburyport, given me by Mr. Sears, by whom they have been briefly described.[1] They are light gray, medium-

[1] SEARS, Bull. Essex Inst., Vol. XXVII, p. 7, 1895.

grained, granitic rocks, showing feldspars, augite, and a few quartz grains. The feldspars are apt to be epidotized. In thin section they show a granitic structure, and are composed of a rather basic plagioclase, about Ab_1An_2, nearly as much orthoclase, considerable quartz, stout prisms of pale green diopside which is commonly uralitized, some pale green biotite also altered, little or no magnetite, and rare small apatites. As all the specimens were badly decomposed I made no analysis of them, but they presumably approach in composition the nordmarkites.

Porphyritic diorite.—A peculiar rock which may be called a diorite is found, along with the orbicular syenite, in similar rounded masses enclosed in granite, near Bass Rock. It is dark-brown, with a rather fine-grained granitic groundmass of white feldspar tables and hornblendes, often surrounded by white feldspar zones, lying in a finer-grained matrix. Through this are scattered large phenocrysts of labradorite, up to 5^{cm} in length, of a peculiar clove-brown color and thick tabular habit. The cleavage of these is very good, and on basal cleavage surfaces fine twinning striations are visible.

Under the microscope the groundmass shows a granitic structure, composed largely of alkali-feldspar, with some plagioclase, small grains of colorless diopside, pale brownish-green hornblende, rare biotite flakes, considerable magnetite in grains and small stout rods, quite abundant apatite and no quartz. The large phenocrysts show well developed twinning lamellæ, which give extinctions corresponding to a labradorite of the composition Ab_2An_3. They are dusty with minute liquid inclusions holding movable bubbles, and also carry inclusions of diopside, hornblende, and magnetite. An analysis was made of a rather coarse-grained piece which was chiefly phenocryst, and this gave:

SiO_2	54.99	CaO	9.87
TiO_2	0.29	BaO	none
Al_2O_3	25.58	Na_2O	4.95
Fe_2O_3	0.43	K_2O	1.11
FeO	2.70	H_2O	0.38
MnO	trace		
MgO	0.72		101.02

This may be calculated roughly to represent:

Orthoclase,	6.5	Diopside,	2.1
Albite,	42.0	Hornblende,	3.2
Anorthite,	44.2	Magnetite,	2.1

Here the albite and anorthite molecules are in the ratio of 1 : 1, but since the microscope shows that the plagioclase has the composition of about Ab_2An_3, it is evident that the alkali-feldspar is rich in soda, and has approximately the composition Or_1Ab_2. The analysis, however, does not represent the composition of the rock as a whole, and for most purposes is of little or no use.

Gabbro.—Rocks which belong to this group are found in typical development only at Nahant, and are called norites by Sears, who has briefly noticed them.[1] According to Wadsworth[2] and Sears, gabbros also occur at various localities in Essex county, especially at Davis' Neck, Cape Ann, and Woodbury Point, Beverly. These, however, judging from the somewhat unsatisfactory specimens in my possession, are rather diorites in Brögger's sense, but will not be described further.

The gabbro of Nahant, as represented by the few specimens collected by myself, are dark, coarse-grained rocks composed of plagioclase, which even in the freshest specimens are dull or waxy and greenish through epidotization and black augite, besides titaniferous magnetite grains. They show both megascopically and in thin section a typically granitic structure.

The abundant plagioclase, although rather decomposed, shows twinning lamellæ whose extinctions correspond to those of a basic labradorite about Ab_1An_3. A little orthoclase is also present. A pale gray augite is abundant, which is often automorphic and shows constantly high extinction angles. In my specimens I could find none of the hypersthene mentioned by Sears. Large titaniferous magnetite grains are common and are often surrounded by borders of leucoxene. With the exception of limonite, epidote, chlorite, and a few other decomposi-

[1] SEARS, Bull. Essex Inst., Vol. XXVI, 1894.

[2] WADSWORTH, Geol. Mag., 1895, p. 208.

tion products, these are the only minerals present. An analysis was made of the freshest specimen, which was slightly altered, from near a cove on the north shore of Nahant, east of the village.

SiO_2	43.73	Na_2O	2.42
TiO_2	4.23	K_2O	1.45
Al_2O_3	20.17	H_2O (110°—)	0.08
Fe_2O_3	4.32	H_2O (110°+)	1.02
FeO	6.93	P_2O_5	0.15
MnO	none		
MgO	3.91		99.40
CaO	10.99		

It is low in silica, rich in lime, but rather poor in magnesia, high in titanium oxide and alumina, and rather high in alkalies for such a rock, which is evidently a true gabbro.

ADDENDUM

"*Hyperitic diorite.*"—Since the description of this rock was put in type an analysis has been made, which renders necessary some corrections and additions. The analysis is given here.

	I	II
SiO_2	45.32	49.25
TiO_2	1.94	1.41
Al_2O_3	18.99	16.97
Fe_2O_3	3.78	15.21
FeO	9.78	
MnO	....	trace
MgO	4.68	about 3.00
CaO	9.19	7.17
Na_2O	3.78	4.91
K_2O	2.12	2.01
P_2O_5	....	0.76
H_2O (110°)	0.09	about 0.30
H_2O (ignit.)	0.31	
	99.98	100.99

I. Hornblende-gabbro, Salem Neck. H. S. Washington anal.

II. Olivine-gabbro-diabase, Dignæs, Gran. A. Damm and L. Schmelck anal. (W. C. Brögger. Quart. Jour. Geol. Soc., Vol. L, p. 19, 1894.)

It will be seen that the rock is decidedly more basic than the other diorites of the region, so far as I am acquainted with them. The silica in fact is lower than that of the diabase and essexite, and closely approaches that of the gabbro from Nahant. This being the case, and the characters otherwise corresponding, the rock is not a diorite in the proper sense, as used by Brögger,[1] but should be called a hornblende-gabbro. It was thought at the time of the microscopical examination that the rock was basic, but it was not expected that it would turn out to be so low in silica as the analysis shows. At the same time the character of the hornblende, which is essentially a barkevikite, the rather high alkalies, and the association with essexite and foyaite show that these hornblende-gabbros ("hyperitic diorites") are decidedly distinct from the other diorites, and approach more closely the essexites and the more soda-rich rocks of the region. Attention has already been called to the fact that they grade into the essexites, and that Rosenbusch grouped them with these, but their decidedly lower alkali content and lack of orthoclase and nepheline sufficiently distinguish them.

It is to be remarked that these rocks resemble very closely under the microscope some of the gabbros of Norway, especially those from the district of Gran, and above all, some from the Viksfjeld. This is seen on microscopical comparison of sections of the rocks, some being mutually indistinguishable, and is also shown by the analyses, one of those of the Gran rocks being given in II for comparison.

H. S. WASHINGTON.

[1] W. C. BRÖGGER, Die Eruptivgesteine des Kristianiagebietes, Vol. I, p. 93, 1894, and Vol. II, p. 35, 1895.

THE SWEETLAND CREEK BEDS[1]

In Muscatine, Bloomington, Sweetland, and Montpelier townships, of Muscatine county, Iowa, some argillaceous beds are frequently found overlying the Cedar Valley limestone These contain a fauna quite different from that of the latter, and are unconformable with this as well as with the Coal Measures above. For reasons which will presently appear it is proposed to call them the Sweetland Creek beds.

Typical exposures.—Following the north bluffs of the Mississippi westward, the first occurrence of these beds is to be seen in the bank of a creek which comes down from the north, just east of the town of Montpelier. About twenty rods north of the bluffs the basal sandstone of the Coal Measures rests on some olive-gray shale, with green bands, rising about three feet from the bed of the stream in the right bank. This shale is altogether unlike the dark shale of the Coal Measures in appearance. The layers are more even and uniform. An unconformity between the two is also evident, and the lower formation soon disappears. In the river bluff the same creek is undermining a cliff of Coal Measure rock, which rests on the Cedar Valley limestone for the greater part of its length, but at the south end the base of the Coal Measures rises somewhat abruptly, first on an eroded slope of the limestone, and then over some decayed yellow clayey beds which intervene and run up ten or twelve feet above the limestone. The present condition of the bank does not afford an opportunity to closely study the nature of the clay beds, but in all probability they belong to the same strata as the shale above.

To the west of the town, a short distance up in Robinson Creek, and just northwest of Mr. G. W. Robinson's residence, some green clay is seen in the south bank of the creek, appar-

[1] Published by permission of the State Geologist of Iowa.

ently resting on the eroded surface of the Cedar Valley limestone. At the base of this clay there is a thin layer of more stony material, and this contains specimens of *Ptychtodus calceolus* and other small fish teeth. This is the basal layer of the Sweetland Creek beds. About one half mile farther up the same creek near the north line of section 23, in Montpelier township, just below a small fall in the creek, the following section is seen.

Number		Feet
13.	Coal Measures.	
12.	Dark bituminous shale with two or three bands of green shale; the dark next the green exhibiting a complex network of thread-like green extensions from ½ to 2^{mm} in thickness, lying approximately parallel with the bedding. Occasional lingulas found	1
11.	Dark bituminous shale with small spheroidal crystalline nodules of pyrites, occasional lingulas and *Spathiocaris emersoni* - -	2
10.	Concealed (next number a few rods farther down) - - -	2 ?
9.	Light greenish shale - - - - - - - - - -	1
8.	Dark olive-gray shale - - - - - - - - -	⅔
7.	Green shale - - - - - - - - - -	⅔
6.	Greenish calcareous shale, almost stony, containing cylindrical or flattened fucoid markings slightly more greenish than the matrix	⅚
5.	Dark gray shale - - - - - - - - - - -	1
4.	Grayish-green pyritiferous rock with minute fragments of unrecognizable fossils - - - - - - - - -	¼
3.	Dark gray shale - - - - - - - - -	¼
2.	Greenish-gray somewhat stony shale exhibiting concretionary conchoidal fractures when weathered - - - - - -	¼
1.	Greenish-gray argillaceous and pyritiferous fine-grained dolomitic rock in layers a few inches in thickness, with fucoid impregnations or markings like those in number 6, ¼ inch in diameter -	1⅔

At the south end of this outcrop there is a small displacement in the ledges, which, dipping at a considerable angle south of it, soon disappear under the Coal Measures. The displacement is no doubt local and probably due to the falling in of some cavern in the underlying limestone.

Westward for the next three miles these beds do not appear, although the contact between the Coal Measures and the Cedar Valley limestone frequently comes into view. In the Pine Creek

basin they must have been removed by erosion previous to the deposition of the Coal Measures. Their next appearance is in Schmidt's run, about a mile east from the railroad station at Fairport. Just north of the wagon road under the bluffs they may be seen in the left bank of the run. There are several outcrops farther up, and the following section was made out, unconformably overlaid by the Coal Measures.

Number		Feet
4.	Dark, almost black shale, with green seams from one to four inches thick, near which the darker shade exhibits a net work of filamentous extensions of green clay	7
3.	Greenish light colored shale	3½
2.	Greenish stony and hard shale	½
1.	Greenish gray soft shale	1½

Just west of the railroad station at Fairport, where a wagon road follows a ravine up the bluff, this ravine exposes the following section.

Number		Feet
7.	Coal Measures resting unconformably on the numbers below.	
6.	Weathered shale of alternate light and dark layers	5
5.	Dark gray shale	5
4.	Grayish-green shale with two bands of darker shale in part perforated by coarse curving filaments or cylinders of green shale	3
3.	Concealed	2 ?
2.	Dark gray shale with curving cord-like cylinders of green shale about ⅙ inch in diameter	3
1.	Greenish argillaceous dolomite in layers about 6 inches in thickness	1

In a small ravine which comes down from the west side of Wyoming Hill there is seen under and north of the wagon bridge about eight feet of gray and green shale with some stony layers. The Cedar Valley limestone comes out in the river bank just below and the Coal Measures overlie the exposure, rising about 100 feet above it.

Along Sweetland Creek the relation of these beds to the formations above and below them is better exhibited than at any other place in the county. About one-third of a mile north from the river bank they come out into view on both sides of

the creek, and they are also seen in a small tributary which runs into the creek from the east. Combining all the exposures at this point the following succession of separate layers is evident.

Number		Feet
11.	Dark gray bituminous shale with one or two thin green bands about four feet below the highest exposure. Occasionally small flat concretions of pyrites are seen. Next the green layer the shale is dark filled with a maze of fine green filamentous lines. Drift overlies - - - - - - - - -	8
10.	Dark shale containing lingulas, *Spathiocaris emersoni*, *Rhynchodus*, and a fossil resembling *Solenocaris strigata*. This number is continuous with No. 11 - - - - - - -	1 ½
9.	Greenish clay with flat concretions of iron pyrites frequently having white stony lamellar extensions from the margin - -	3
8.	Dark shale - - - - - - - - - - - -	⅔
7.	Greenish stony shale with a conchoidal concretionary fracture, -	⅓
6.	Hard light grayish-green shale with white flattened cylindrical fucoid concretions of a concentric structure in horizontal positions -	¼–½
5.	Greenish argillaceous or arenaceous fine-grained dolomite in ledges from 4 to 10 inches in thickness, with occasional lingulas and a fragment of a cast of a gasteropod near the base, frequently exhibiting small cylindrical concretionary impregnations of a deeper green, and occasionally impressions of plant-like fibrous structure covered with a thin layer of bituminous material -	3
4.	Greenish shale - - - - - - - - - - - -	1 ½
3.	A stony seam filled with finely granular pyrites and occasionally showing larger lumps of the same mineral in one instance associated with plant-like fibrous impressions, frequently containing rounded worn fragments of fish teeth - - - - -	$\frac{1}{12}$–¼
2.	Green hard shale - - - - - - - - - - -	⅔
1.	Greenish stony layer with frequent, mostly rounded, fragments of *Ptychtodus calceolus* - - - - - - - - -	⅓

Under the lowermost layer containing fish teeth the uneven surface of the upper ledges of the Cedar Valley limestone is seen, and at least eight feet of this rock is exposed. In some of the shallow depressions in its upper surface a seam of black bituminous material is found. At one point this forms a layer two inches in thickness. Near the south end of the exposure farthest down the creek the upper beds come down over the

uppermost ledge of the limestone, which runs out as if worn away. The surface of the limestone has been partly uncovered by the creek. It is brown in color, uneven from erosion and frequently studded with nodules of iron pyrites or covered by a continuous incrustation of the same mineral. In the west bank of the creek the basal sandstone of the Coal Measures overlies the eroded edges of numbers 6, 7, and 8 in the above section, which rise under it in a hillock. In the gully to the east the section is continued higher up and the Coal Measures do not appear. Some distance farther up Sweetland Creek they are again seen unconformably overlying the dark gray shale in the east bank, with erosion contours extending down three feet into the lower formation. At this place the basal conglomerate contains rounded lumps of the dark shale, three or four inches in diameter. Still farther up the creek the darker shale corresponding to number 11 in the above section appears at several places in the bed of the stream, rising in one instance about five feet in the bank. The last seen is about one hundred paces south from the wagon bridge near the north line of section 27. In each of these places the characteristic green layers with their accompanying network of green threads in the confining dark shale may be seen.

About three fourths of a mile west of Sweetland Creek, near the east line of section 28, in Sweetland township, a smaller stream exposes the following section.

Number		Feet
5.	Coal Measures.	
4.	Alternate layers of dark and greenish shale - - - - - -	4
3.	Fine grained, light yellowish-gray, impure dolomite in thin ledges	2½
2.	Greenish shaly rock with a thin, harder layer below - - - -	2¼
1.	Upper ledges of the Cedar Valley limestone, ferruginous and worn superficially - - - - - - - - - -	1–2

In Camhel Run, which comes down to the river through the northwest corner of section 21, in the same township, a similar succession of layers is seen at the point where the stream passes the line of the river bluffs. The following section appears very clearly.

Number		Feet
11.	The base of the Coal Measures.	
10.	Dark gray shale with lingulas near the base - - - - - -	3
9.	Greenish shale - - - - - - - - - - - - -	3½
8.	A layer of harder, almost stony shale - - - - - - -	½
7.	Greenish-gray shale weathering with a conchoidal fracture into small spheroidal nodules and chips - - - - -	1 ±
6.	Grayish, fine grained, impure dolomite - - - - - - -	1½
5.	Greenish shale - - - - - - - - - - - - -	1 ±
4.	A thin and stony, in places highly pyritiferous seam, associated with small selenite crystals when decayed, in places almost filled with rounded specimens of *Ptychtodus calceolus* -	$\frac{1}{10}-\frac{1}{5}$
3.	Greenish shale - - - - - - - - - - - - -	½–1
2.	Greenish fine-grained rock with fish teeth - - - - -	⅙–¼
1.	Upper ledges of the Cedar Valley limestone with a slightly eroded surface, frequently covered with pyrites.	

Number 10 in the above is seen in two or three places farther up in the creek, but it soon disappears under the base of the Coal Measures.

Along Geneva Creek, in the northwest quarter of section 29, in the same township, the basal layers of the preceding sections are seen in the bed of the stream opposite the Geneva schoolhouse, and below the wagon bridge. The main stony ledge forms the bed of the creek for a distance of ten or twenty rods a quarter of a mile farther up. About half a mile north of the schoolhouse the shale above this ledge rises some six feet in the west bank, and is overlaid by the basal conglomerate of the Coal Measures, from which a small spring issues. Combining these exposures the succession of the layers seen may be given as in the following section.

Number		Feet
13.	Basal conglomerate and sandstone of the Coal Measures.	
12.	Dark gray and ferruginous, evidently somewhat disintegrated dark shale - - - - - - - - - - - - -	$\frac{4}{5}$
11.	Light greenish-gray shale - - - - - - - - - -	$\frac{4}{5}$
10.	Dark lavender colored shale - - - - - - - - -	1⅙
9.	Green shaly rock - - - - - - - - - - - -	½
8.	Concealed - - - - - - - - - - - - - -	?
7.	Green rock in even thin layers with regular vertical rather equidistant joints - - - - - - - - - - - -	1½

Number		Feet
6.	Concealed	?
5.	Greenish shale (opposite the schoolhouse)	1
4.	Pyritiferous green stony layer with cylindrical straightish fucoid impregnations	$\frac{4}{6}$
3.	Green shale	1
2.	A conglomerate of fish teeth, containing *Ptychtodus calceolus* and *Synthetodus* frequently in a worn condition and imbedded in a greenish argillaceous fine-grained dolomite	¼
1.	Beds of the Cedar Valley limestone containing large fragments of Stromatopora, with the upper surface unevenly eroded.	

From this point westward no more is seen of the beds under consideration until we come to East Hill, in Muscatine. Under the south bluff of this hill the railroad bed has been excavated in the upper dark shale seen in the foregoing sections. These rise here about thirty feet above the bed of the road, and they have been so disposed to slip in the bank, that piles and a stone-wall have for many years been needed to keep the embankment from coming down on the track. These were removed late last fall and the face of the embankment was cut away several feet. This work left the shale well exposed. The section above and below the railroad bed is as follows.

Number		Feet
2.	Dark or gray bituminous shale, with three parallel bands of green shale a few inches in thickness and about three or four feet apart, weathering into fine chips of a yellowish light gray color, containing small flat concretions of pyrites, joints in some of the freshly exposed shale filled with numerous small crystals of lenite disposed in branching patterns, the basal part containing sea lingula and exhibiting the peculiar network of green thread-like extensions observed in previous sections near the transitions to green shale	36
1.	Green shale	2

The top of number 2 is unconformably overlaid by the Coal Measures, and has evidently been weathered previous to their deposition. Below number 1 the section is concealed in the river bank. The base of this layer is about ten feet above low water. There is little doubt that it is the equivalent of number

9 in the Sweetland Creek section, and the lower layers of these beds may possibly all have been exposed above water at this point before the railroad embankment was made. As these lower layers aggregate about seven feet in thickness at other places, it will be noticed that the extreme thickness of the whole formation at this place is about forty-five feet. This is the greatest thickness that has been seen anywhere in the county.

Just above the wagon bridge which crosses Mad Creek near the center of the northwest quarter of section 24 in Bloomington township, some ledges equivalent to numbers 6, 7, 8 and 9, in the Sweetland Creek section appear in the bank of a tributary from the east. Again in the creek running east through the north half of the northwest quarter of section 26 in the same township some thin ledges of rock and some green shale corresponding to numbers 3, 4, and 5 in Sweetland Creek come into view from under some Coal Measure beds.

Geographical distribution.—So far as known, the above places include all the exposures of the Sweetland Creek beds in the county. There is good reason to assume that they underlie the Coal Measures in most of Muscatine, Bloomington, and Sweetland townships, and that scattered outliers occupy the same position in the east half of Montpelier township. In all probability their outcrop in the river bluff is continuous from Wyoming Hill to Muscatine, though mostly concealed by the talus under the bluffs.

General section.—The separate layers and ledges of the formation have a remarkably uniform development, varying but slightly in different places. The basal layer, though only about three inches in thickness, can always be recognized in its place, and invariably contains the characteristic fish teeth. From six inches to a foot above this layer there is a pyritiferous stony seam from one-half to two inches in thickness, and this is readily identified in all the creeks in Sweetland township where the lower part of the section appears. The peculiar maze of green threads which extend into the dark shale where this comes into contact with green layers have been observed in almost every case where

they are due in the section, all the way from Muscatine to Montpelier. It is therefore no very difficult task to combine the local outcrops into a general section.

GENERAL SECTION OF THE SWEETLAND CREEK BEDS

Number		Feet
7.	Dark bituminous shale, occasionally containing small flat concretions of iron pyrites, with three thin bands of greenish shales respectively about 5, 9, and 12 feet from the base - - -	33
6.	Dark shale, with thin seams of blue shale, the dark containing two species of lingula, *Spathiocaris emersoni*, *Rhynchodus*, and a fossil resembling *Solenocaris strigata* - - - - - -	3
5.	Greenish shale, with occasional stony layers, containing flat concretions of pyrites frequently bordered by lamellar marginal extensions of a white dolomitic material - - - -	3½
4.	Alternating layers of greenish stone and green and dark shale, the latter in part containing a network of thread-like extensions of the former. The green shale has elongated flattened concretions resembling fucoid growths and lying parallel with the bedding. The stony layers are frequently charged with small grains of pyrites and contain minute fragments of fossils - - -	2
3.	Greenish fine-grained argillaceous magnesian limestone impregnated with iron pyrites and calcium phosphate, in ledges from 4 to 10 inches in thickness, with cylindrical fucoid impregnations slightly more greenish than the matrix and from 3 to 6 millimeters in diameter, containing two species of lingula, a fragmentary cast of a helicoid gasteropod, and imprints of some fibrous structure like that of some plant stem - - -	3½
2.	Hard greenish-gray shale, with a stony pyritiferous layer that contains fish teeth and impressions of vegetable tissue about 10 inches from base - - - - - - - - - -	3
1.	Argillaceous dolomitic stony layer containing *Ptychtodus calceolus* and other forms resembling *Synthetodus* - - - -	¼

Lithological peculiarities.—The greenish ledges turn grayish-yellow on weathering. The main stony ledge, number 3, often protrudes as a shelf over the clay below it, which is more easily removed by erosion. In two instances an efflorescence of epsomite was noticed forming on the face of the clay thus protected from rain by the overhanging rock. The material found in the shells of the lingulas of this ledge was unaltered, but

in one instance slightly dissolved away. The tubular impregnations in the stony layers of the formation appear to be marked off from the mass of the rock so as to sometimes weather out like casts of fucoid stems. In other instances they appear like slightly more colored parts of the rock. The thread-like extensions of green clay which form a network in the dark shale at some horizons where it comes in contact with the lighter shale vary in coarseness at different places. There is nothing to indicate a structural boundary between the green in the threads and their dark matrix, and there is hardly anything to suggest that they have an organic origin. It seems more likely that they have resulted from some progressive change in the mineral nature of the shale. Excepting the lingulas, the fossils which occur in the layer numbered 6 in the general section are all of a black and bituminous substance, which is apt to break and fall out in drying, leaving only a mold. The dark shale in numbers 6 and 7 is fine and very uniform in character. Occasionally it is difficult to distinguish from the Coal Measure shale, but the latter usually contains small mica scales, which are absent from the former. Where not weathered, these beds contain a considerable amount of bituminous material, which on distillation yields inflammable gas and oil. The several layers of the formation have been examined for phosphate by Dr. J. B. Weems, who finds 2.01 per cent. in number 7, 1.94 per cent. in number 6, 2.09 and 2.18 per cent. respectively in two analyses of material from number 5, 3.18 per cent. in number 4, 6.82 and 5.29 per cent. respectively in two analyses of material from number 3, 5.43 per cent. in number 2, and 4.86 per cent. in number 1.

Structural Relations.— As already shown, a pronounced unconformity separates this formation from the overlying Coal Measures. The erosion interval preceding the deposition of the latter has left its marks, not only in the reliefs which extend from the top of these beds to a considerable distance below their base into the underlying limestone, but also in the weathering of the Sweetland Creek beds, especially where these rise

high. In such places the lamination appears indistinct, and the shales are oxidized and leached. After the deposition of the Sweetland Creek beds they were raised and subjected to erosion and sculpturing, which no doubt removed the greater part of them. Only remnants are left. Then, again, the land was submerged, and the topography just sculptured was covered over by the variable shore deposits of the Coal Measures.

It has also been shown that there is an unconformity with the underlying Cedar Valley limestone. But this unconformity indicates altogether different conditions. The upper formation is, in this case, not a shore deposit. The basal member of the Sweetland Creek beds is a thin layer of argillaceous dolomite containing no littoral detritus, and it is unusally uniformly developed, though only two or three inches thick. It is a sediment made in the sea at such a slow rate that the teeth of dying fishes accumulated rapidly enough to make at one place as much as one fourth of its bulk. This layer follows the small inequalities in the surface of the lower rock like a mantle. None of these are very high or deep. On a distance of a few rods none appear to exceed two feet in vertical extent. Near the Geneva school the basal tooth-bearing layer appears to occupy a place eight feet lower than the highest ledge in an abandoned quarry close by. The surface of the limestone is, however, plainly eroded and apparently to some extent oxidized. In the east bank of Sweetland Creek the highest ledges of the limestone run out to the south, and the overlying formation comes down over their beveled edges. An unconformity of this kind is most likely caused by subaqueous erosion, due to marine currents, followed by renewed sedimentation in the same sea. Such events may have been accompanied by an approach of the shore line. This is, perhaps, indicated by the presence of faint traces of vegetation in the later member in this case. But at the very beginning of the second accumulation the shore was not near enough to leave a trace of anything coarser than clay. Even this was scarce at first, when calcareous sediments predominated. The persistence of each thin layer over distances of several

miles goes to show that the conditions under which they were laid down were uniform over wide areas, and such conditions are not to be found in the proximity of the shore line. Everything considered, this unconformity was most likely caused by changed conditions in the sea and its currents, in all probability consequent upon some orogenic movements affecting the ocean basin.

Fossils.—The fossils so far found in this formation are few, but they are many enough to indicate that it must be referred to the Upper Devonian, or the Chemung. The fibrous plant-like impression from number 3 was found extending over a slab a foot long and about three inches wide. In the pyritous layer in number 2 there was a similar, much smaller, impression. The mold in both instances was covered by a bituminous crust an eighth of an inch in thickness. In this no organic structure could be detected. The lingulas which occurs in numbers 3 and 6 have been submitted to Dr. Charles Schuchert, who says that one species is apparently identical with an undescribed species, from nodules in the "Black Shale," or the Genesee; one is related to *L. melie* Hall, from the Cuyahoga shale; and another to *L. nuda* Hall, from the Hamilton. The author has also observed one lingula in number 6, which resembled *L. subspatulata* M. and W. Some small bilobate fossils from the same number in the general section have been examined by Dr. J. M. Clarke, who has reported that they are identical with *Spathiocaris emersoni* Clarke. This fossil occurs in the Portage group in New York, and has not previously been reported from the West. In the same layer the author found one fossil which resembled *Solenocaris strigata* Meek. This form is known to occur in the "Black Shale" of the Ohio valley. The cast of a gasteropod, found in the stony ledge number 3, was too fragmentary for more exact determination. Dr. C. R. Eastman has examined all the fish remains found, and states that the greater number of the teeth from numbers 1 and 2 are *Ptychtodus calceolus* M. and W. He finds them on the average smaller than usual, but in other respects perfectly like the type. He also reports that there are several other forms of flat, crushing teeth, which are allied to

Synthetodus from the State Quarry fish bed in Johnson county. From the bituminous dark shale, number 6, he identifies a Rhynchodus, related to *R. excavatus* Newb., from the Hamilton in Wisconsin.

LIST OF FOSSILS IN THE SWEETLAND CREEK BEDS

Impression of plants.	
Lingula, sp. undet.	Identical with one from the Black Shale
L. cf. melie Hall	Cuyahoga Shale
Lingula, cf. nuda Hall	Hamilton
Lingula subspatulata M. and W. (?)	Black Shale
Spathiocaris emersoni Clarke	Portage Shale
Solenocaris strigata Meek (?)	Black Shale
Gasteropod	
Ptychtodus calceolus M. and W.	Hamilton and State Quarry Beds
Synthetodus	State Quarry Beds
Rhynchodus, cf. excavatus Newb.	Hamilton

Additions will no doubt be made to this list. As it is, it indicates a correlation with the Upper Devonian of New York, and more particularly with the Devonian Black Shale of the interior, which also is regarded as a part of the Upper Devonian. To this shale it shows another resemblance in having the basal layers stony and containing a comparatively high per cent. of calcium phosphate, while the upper part is a black shale. It will be remembered that in Perry and Hickman counties in Tennessee the Black Shale changes downward into the phosphate rock.[1]

This comparison may be better shown in tabular form.

RELATION OF DARK SHALE TO PHOSPHATE BEARING ROCK IN IOWA AND IN TENNESSEE

Iowa			Tennessee
Bed No. 7 contains 2.01 % of phosphate	Dark Shale		Black Shale containing little or no phosphate
" " 6 " 1.94 % " "			
" " 5 " 2.13 % " "			
" " 4 " 3.18 % " "	Variable beds		
" " 3 " 6.05 % " "	Greenish gray pyritiferous rock and shale		Light gray to bluish-black phosphate rock, with disseminated pyrites
" " 2 " 5.43 % " "			
" " 1 " 4.86 % " "			

[1] See the Tennessee Phosphates, by C. W. HAYES, Seventeenth Ann. Rep. U. S. Geol. Surv., Part II.

The indicated correlation appears all the more probable, as there exists under the phosphate-bearing rock in Tennessee an unconformity, which is believed to be due "not to the existence of a land area and subaërial erosion, but rather to non-deposition, by reason of strong marine currents."[1] The renewal of the conditions of sedimentation in the paleozoic sea in the late Devonian age may not have been quite simultaneous in the two localities, though nothing is known to indicate the contrary, but there seems to have been at any rate a parallel in the sequence of events.

J. A. Udden.

[1] Loc. cit., p. 534.

STUDIES IN THE DRIFTLESS REGION OF WISCONSIN

In my previous articles under the above title I have stated that no glaciated material had up to that time been found. Indeed I was not very hopeful that any would be found, for not only are the beds concealed to a very large extent, but the parts exposed are those which would naturally be composed of superglacial and englacial material. Add to this the fact that the glaciers if really prescribed, were but a few thousand feet long at the utmost, and the further fact that even of this short distance a considerable portion was over loess of earlier deposition and it will be seen that such material must necessarily be scanty. Nevertheless in view of the extreme difficulty of determining the original aspect of the beds in many important particulars it was very desirable that the evidence which could be furnished by glaciated material should be added to that already given. I think it very fortunate therefore that during the past summer I have discovered a bowlder which gives very strong if not decisive indications of glacial abrasion, and inasmuch as it will form a most important part of the evidence for the existence of glaciers I will describe it in considerable detail.

The bowlder lies at the bottom of a ravine, well within one of the smaller valleys. It is about 10 in. × 14 in. × 26 in. in dimensions. The material is a rather hard, course-grained ferruginous sandstone, such as occurs a little below the base of the Lower Magnesian limestone. Its rather rough uneven surface is the product of prolonged weathering, but at one end there is a facet forming an irregular oval about 6 in. × 8 in. which contrasts strongly with the rest, being nearly flat, and very noticeably smoother to the touch. Examination with a lens shows that this smoothness is due to the relatively small projection of the individual sand grains, few standing out more than a third of their diameter above the general surface, while on the

weathered portions they often project nearly their entire diameters.

It is evident that the resistance of the sand grains to abrasion was greater than the strength of the cementation, so that the abrading agent removed them integrally instead of wearing them down to a common surface. There is, however, near one edge of the facet a small concretionary nodule within which the great abundance of iron furnishes a strong cement. In this the individual grains *are* worn to a common surface, the effect being equal to the best examples of glacial polish. A portion of this concretion passes over onto the weathered surface where the grains are all entire, and owing to the strong cementation many of them are held as the capping of little pedicels, giving a very rough surface. The bedding plane of the bowlder is parallel to its longer diameters, and the flattened facet is nearly perpendicular to this. The facet is crossed in a direction perpendicular to the bedding plane by a straight groove about ¼ in. wide and deep enough to render it perfectly distinct. Other markings are but faintly shown, but so far as they are distinguishable they are parallel to the groove.

It appears quite evident that this abraded facet was superimposed on an originally weathered surface, for sundry depressions occurring within it were not affected by the abrasion, but still retain their original weathered character. Taking all these features into consideration I think it may be said that they are such as are characteristic of glacial abrasion, while it is hard to suggest another agent by which they could have been produced. Certainly none which we have the least reason to believe was operative in the locality.[1]

I have mentioned that the bowlder lies at the bottom of a ravine. It may therefore be well to add that although it is exposed to the action of the occasional torrents, yet the facet in question is turned away from them, while that portion which

[1] It would seem that abrasion of this kind and extent might be within the competency of the friction to which ordinary talus is liable to be subjected in descending a slope.—Ed.

does receive their impact (and has certainly for a long time) is indistinguishable from the rest of the weathered surface. But the results of torrential abrasion are so different from those described that it need not be seriously considered as a possible agent.

If this be a case of glacial abrasion, and it is difficult to resist such a conclusion, it must necessarily decide the question as to the existence of small local glaciers, since its situation is such that if glaciated at all it was certainly the work of such local glaciers.

It was my hope during the season just passed to make a series of observations at critical points with a view to a more definite determination of certain doubtful features, but owing to a pressure of other work they were for the most part left incomplete. On two points, however, evidence of considerable value was obtained. The first relates to the frontal characteristics of the bowlder beds, especially the frontal slope. This appears to have been normally steep as compared with the portion immediately back of it along the axis of a valley.

This characteristic is shown in two or three of the beds which fail to reach the present river level, but as they fall within the limits of the highest terrace it is open to question whether the effect was not due to erosion when the river was at that stage. But I have ascertained that the same characteristic is found in beds which terminate a hundred feet or more above this level. Still another bed extends to the present river level and has been truncated by river erosion, but gives no indication of erosion at the higher level, although by situation it was especially exposed to erosive action — far more so than the other beds which were well protected from currents.

The second relates to the disposition of the beds along the sides of the valleys showing that on reaching their rocky sides the beds rise to higher level than along the axes of the valleys, This is not hillside wash since the material is foreign to the hills on the sides of which it occurs.

Assuming these beds to be glacial an interesting question is

raised as to their synchronism with the successive phases or epochs of the glacial period.

Before this can be answered other than conjecturally it will be necessary to correlate them with the succession of non-glacial deposits filling the larger valleys of the driftless region, a work of considerable difficulty.

G. H. SQUIER.

A DISCUSSION AND CORRELATION OF CERTAIN SUBDIVISIONS OF THE COLORADO FORMATION

A FAIRLY accurate correlation of the subdivisions of the Colorado formation in the central-interior province is not difficult. Although the work done in the different areas of the province has been largely independent, yet divisional lines are not strikingly inharmonious. Points of separation are more easily determined in certain areas than in others. In specific parts of the province confusion in regard to divisional lines seems to have arisen, due to misinterpretations of a palæontological nature, while in other parts the confusion seems to be due to lithological similarities. The points involved are, on the whole, minor ones, and, perhaps, are not worthy of any very elaborate discussion. Nevertheless, stratigraphical geology is, at its best, complex, and therefore should receive every additional contribution which will tend to relieve its comlexity.

The Colorado formation has not been studied as thoroughly and systematically as is desired, yet a study has been made of a sufficiently large number of areas to warrant the establishment of more general division lines. The areas of the central-interior province which have been studied somewhat in detail are: The southeastern Colorado area, the Black Hills area, the eastern Dakota area, the Iowa-Nebraska area, and the Kansas area. Since I am more familiar with the detailed stratigraphy and palæontology of the last-named area I will discuss it and use it as a standard by which to correlate the other areas.

In the Kansan area two principal groups have been recognized for the Benton series. These groups are, the lower or Limestone group and the upper or Shale group. The division is based primarily on lithological grounds as the names indicate. The Limestone group admits of five subdivisions, such divisions

being made on either palæontological, lithological or economic conditions. The subdivisions are: The Bituminous Shale, the Lincoln Marble, the Flagstone Beds, the Fencepost Beds, and the Inoceramus Beds. The Shale group has two divisions, the Ostrea Shales and the Blue Hill Shales. The Niobrara series is divided into the Fort Hayes Limestone and the Pteranodon group, the latter being further divided into the Rudistes Beds and the Hesperonis Beds.

FORT BENTON

The bituminous shale.—Although I have named these beds as one of the subdivisions of the Limestone group I prefer to discuss them separately for convenience of correlation. The Bituminous shale is a moderately compact argillaceous shale which in some localities is somewhat calcareous. The prevailing color of the shales at the base of the beds is dark blue, which passes to light gray at the upper limit. The beds contain the remains of a marine fauna, since plesiosaurs' bones, sharks' teeth, and impressions of Inoceramus are found in them. The maximum thickness of the stratum is not more than twenty-five or thirty feet.

In the Arkansas valley in Colorado its stratigraphical equivalent, the Graneros shales,[1] reach a thickness of 200 feet. In the Huerfano area[2] these shales have a thickness of 100 feet. Near Sioux City, Iowa, and Ponca, Nebraska,[3] a bed of shales, having a thickness of forty feet, occupies the same geological horizon and possesses primarily the same characteristics. In the Black Hills area near Buffalo Gap these shales have a thickness of more than twice that of the Eastern area, being in the neighborhood of 100 feet in thickness. The stratum appears to be very persistent, occurring in all the known areas of the cen-

[1] GILBERT, G. K., The Underground Waters of the Arkansas Valley in Eastern Colorado, Seventeenth Ann. Rept. U. S. Geol. Surv., 1896.

[2] STANTON, The Colorado formation and its Invertebrate Fauna, Bull. U. S. Geol. Surv., 1893.

[3] CALVIN, The Relation of the Cretaceous Deposits of Iowa to the Subdivisions of the Cretaceous proposed by Meek and Hayden, Am. Geologist, Vol. XI.

tral-interior province. And although it varies much in thickness its faunal and lithological characteristics are remarkably uni form.

The Limestone group.—The Limestone group is recognized in all the areas except the Iowa-Nebraska and Eastern Dakota areas. Subdivisions have not been designated for the group in any of the areas except the Kansan. Although the subdivisions are persistent the divisional lines are arbitrary for the beds grade into each other. The Lincoln Marble is more easily differentiated on both palæontological and lithological grounds. It has a remarkably interesting and unique fauna. In the shallow marine waters where its beds were deposited, foraminifera, corals, and oysters were associated with sharks, fish, turtles, and saurians. The rock is composed almost wholly of foraminiferal remains, in which are imbedded sharks' teeth, fish teeth, shells, and other animal remains. So abundant are the teeth in certain portions of the rock that it gives a reddish hue to the surface on which they have been rendered visible by weathering.

The beds are composed of thin layers of a compact close-textured limestone, having an average thickness of three or four inches, and susceptible of moderate polish. On account of the last-named characteristic it is called, locally, marble. The limestone layers are separated by thin beds of shale of about the same thickness. The assumption that these beds are of shallow water origin is based on the presence of quantities of carbonaceous matter in the limestone and the highly carbonaceous character of the intercalated shale beds. Numerous fragments of fossilized trees and charcoal have been discovered in the beds in the Kansan area.

The Lincoln marble is notably persistent in the Kansan area. The same is true of the Black Hills area. In the latter area the layers of limestone are somewhat arenaceous, but the faunal characters are similar, as fish teeth and saurian bones have been noticed. It is presumable that when a careful study is made of the Benton stratigraphy in other parts of the province that the Lincoln marble will be differentiated. Such is not so likely to

be true in the case of the other subdivisions of the Limestone group, since the criteria are not so pronounced.

In the Iowa-Nebraska area, according to descriptions given of that region, the Benton limestone group seems to be entirely wanting. This may be due to a misunderstanding in regard to the proper position of the division line between the Benton and the Niobrara. The following is a description of the Benton in that region.[1] "Shales are more or less unctuous to the feel, somewhat variable in color and texture, containing remains of saurians and teleost fishes, the upper beds sometimes bearing impressions of *Inoceramus problematicus;*" while the Niobrara which rests upon the above described Benton shales is described as follows: "Calcareous beds consisting of chalk and thin bedded limestones, containing shells of *Inoceramus problematicus*, *Ostrea congesta*, and teeth of *Odotus*, *Ptychodus*, and other selachians; thickness, thirty feet."

It is not improbable that a part of these thirty feet of so-called Niobrara should be assigned to the Benton, since, in speaking further of the beds, the author says: "These (beds) consist in part of soft chalky material and in part of fissile limestone that divides under the hammer or on exposure to the weather, into relatively thin laminæ crowded with detached valves of *Inoceramus problematicus*."

The above describes exactly the Inoceramus beds of the Benton in the Kansan area. In that area *Inoceramus labiatus*, syn. *problematicus*, makes its appearance in the upper Bituminous shale beds, and continues to increase in numbers until the Inoceramus beds are reached, where it attains the acme of its abundance. It then declines in numbers to the Blue Hill shale horizon, where it disappears altogether, and if it reappears at all in the Niobrara it is very rare.

The geological range of the species is confined to the lower Benton, and although its zone appears to be narrow its geological distribution is exceedingly wide, as it is reported from nearly all known Cretaceous areas. Mr. Gilbert[2] mentions it as the

[1] CALVIN, loc. cit.

[2] Loc. cit.

characteristic fossil of the Benton limestone in the eastern Colorado area, and also speaks of its abundance in certain layers. *Inoceramus labiatus* has been confused in certain areas with *I. deformis* and other species of the same genus. This confusion has arisen on account of its reported association with *Ostrea congesta*. *Ostrea congesta* occurs in the Benton, where it is found adhering to a large nearly flat *Inoceramus*, but is never found adhering to the much smaller species, *Inoceramus labiatus*. In fact, it is rarely found associated with that species. *Ostrea congesta* occurs also in the Niobrara. It is here found attached to *Inoceramus pennatus*, *I. concentricus*, *I. platinus*, *Radiolites maximus* and other large shells. *Inoceramus sp.*, to which the ostreæ of the Benton are attached, resemble *Inoceramus platinus* of the Niobrara, but on account of the extreme brittleness of the Benton shell, due to its transversely fibrous structure, whole specimens cannot be obtained for examination.

But there is a distinction between the forms of the adhering ostreæ. *Ostrea congesta*, var. *Bentonensis* is a small thin subtriangular shell which, if permitted to grow uninterrupted, is almost flat. The upper valves are so thin that they are rarely preserved. *Ostrea congesta*, var. *Niobraraensis* is a larger, thicker shell, with the lower valve more capacious, and possessing near the hinge area well-marked vertical lines of muscular attachment. The upper valve is also thick, and in many specimens possesses adhering forms of the same species. The differences may not be marked enough to be considered specific differences, but they are sufficiently well developed to distinguish the two forms. It is well to bear in mind then that there is a species of *Inoceramus* in the Benton which possesses adhering forms of ostreæ, and that there is a similar species in the Niobrara possessing them, and that therefore *Ostrea congesta* adhering to *Inoceramus* cannot be taken as a criterion for either group unless the ostreæ are properly differentiated.

The shale group.—Resting upon the limestone group is a bed of shales called the Ostrea shales on account of the abundance of that fossil in them. These shales are argillaceous, so much

so in places that they might with propriety be called clay, and are variable in color. The prevailing color is dark blue. Here and there in the shales are thin beds of limestone containing *Inoceramus labiatus* and species of cephalopods. *Ostrea congesta*, var. *Bentonensis* attached to *Inoceramus sp.*, is the most abundant species. Fish teeth, sharks' teeth, and pavement plates and fossil wood containing species of *Parapholæ*, also occur. Near the upper limit the shales contain a species of *Inoceramus* with *Serpula plana* attached. The thickness of the Ostrea shales in the Kansan area is 150 feet. They are the stratigraphical equivalent of the lower Carlile shales in the eastern Colorado area. The Black Hill area possesses a bed of shales twenty or thirty feet in thickness, which is stratigraphically and palæontologically equivalent to the Ostrea shales. Specimens of *Serpula plana* and *Inoceramus labiatus* were found in an outcrop of the shales on Hat Creek, a southern branch of the Cheyenne River. The Ostrea shales in this area are somewhat arenaceous, and the prevailing colors are blue and light yellow. The Ostrea shales are wanting in the Iowa-Nebraska and eastern Dakota areas.

The Blue Hill shales.—The Blue Hill shales form the upper zone of the shale group. They are dark or slaty colored shales which, under the influence of weathering, break up into very fine, chaff-like fragments which are so light as to be moved about somewhat easily by the wind. On account of their fine, laminated appearance the shales are sometimes called paper shales. They are unfossiliferous and homogenous, except in the upper third. This zone has numerous argillaceo-calcareous concretions called septaria imbedded in its shales. Some of these concretions possess the cone-in-cone structure, while others are formed of concentric layers. Fissures in others of the concretions have been filled in by sedimentation with calcite which ranges in color from white to claret. These are the true septaria. Many of the concretions are highly fossiliferous. The following species have been collected from them: *Scaphites larvæformis*, *S. vermiformis*, *S. warreni*, *S. ventricosus*, *S. mullananus*, *Rostellites willistonii*, *Pri-*

onocyclus Wyomingensis, *Placenticeras placenta*, *Inoceramus undabundus* and *I. tenuirostratus*.

In the Kansan area the Blue Hill shales have a thickness of 100 feet. The upper Carlile shales form their stratigraphical equivalent in the Colorado area. The septaria zone occurs in relatively the same position in the Carlile shales, and presents approximately the same lithological characteristics. The total thickness of the Carlile shales is from 175 to 200 feet, including the upper and lower beds, the equivalents of the Blue Hill and Ostrea beds. In the Black Hills area a bed of shales thirty to forty feet in thickness, bearing calcareous concretions of the cone-in-cone structure is the stratigraphical equivalent of the Blue Hill shales. The Blue Hill shales as well as the Ostrea shales have no equivalent in the Iowa-Nebraska and eastern Dakota areas.

THE NIOBRARA

The division line between the Benton and the Niobrara in the Kansan area at least is not an arbitrary one. Lithologically it marks a change from dark argillaceous shale to comparatively pure chalk of remarkable whiteness, scarcely compact enough to deserve the name limestone. The change is one of abruptness, there is no transition zone. The shale does not appear again. A massive stratum of limestone rests upon the dark shales, and there is no intermediate layer, part chalk and part shale. Palæontologically the change is marked by the ushering in of an almost entirely new fauna.

Two principal divisions of the Niobrara are recognized in the Kansan area. These are the lower or Fort Hays limestone and the upper or Pteranodon beds. The division may be said to rest on both lithological and palæontological grounds. The Pteranodon beds are further subdivided into the Rudistes and Hesperonis beds. This division is made on purely palæontological evidences.

The Fort Hays limestone.—The Fort Hays limestone is in massive layers of from two to four feet in thickness, and the

total thickness of the bed is fifty to sixty feet. When taken from the quarry it is very soft and easily cut and carved into any desired shape. It hardens somewhat on exposure. The lower portion, except for the minute cocoliths and foraminiferæ is largely unfossiliferous. The upper portion contains many species of invertebrates.

In the Colorado area the lower fifty feet of the Timpas beds is the equivalent of the Fort Hays. The zone is described as being composed of layers of a compact, rather fine-grained limestone of a light gray color which becomes creamy white on weathered surfaces. The layers are from a few inches to three feet in thickness, and are separated by thin beds of shale usually one or two inches thick.[1]

In the Black Hills area the position of the Fort Hays is occupied by a bed of shales containing a layer of limestone two feet in thickness. In the Iowa-Nebraska area it seems probable that the Fort Hays beds rest upon the Benton limestone, but the line of separation may be difficult to establish. In the eastern Dakota area the equivalent stratum reaches a thickness of 130 feet.

The Pteranodon beds.—The upper division of the Niobrara comprises the true chalk of the Kansan area. The chalk varies in color from a light blue through lavender, yellow, and buff, to red and orange. Under fresh exposure it presents the appearance of a blue shale, and has often been taken for such. The freshly exposed beds, however, under the weathering influence of air and water, soon change their shale-like appearance and blue color. The change in color is probably due to a chemical change in the iron compounds in the chalk. Chert beds occur in some places interstratified with the chalk. These are only of very local occurrence, however. The chalk is used to some extent as a mineral pigment in the manufacture of paint. Fossil wood is not of rare occurrence in the chalk, and it is frequently found pierced with the shells of *Parapholæ*. Fragments of amber[2]

[1] GILBERT, loc. cit.

[2] WILLISTON, The Niobrara. Kan. Univ. Geol. Surv., Vol. II.

have been obtained from some of the specimens of fossil wood. Charcoal also occurs in the chalk as well as in the Benton limestone. Nodules of pyrite are abundant in some outcrops.

The lower Rudistes beds present a varied and extensive invertebrate fauna. The Hesperonis beds contain fewer invertebrates, but a vastly greater number of vertebrates than the lower Rudistes beds.

The upper 125 feet of the Timpas beds is probably the equivalent of the Rudistes beds, while the Apishapa beds are the equivalent of the Hesperonis beds in the Colorado area. In the Black Hills area the position of the Pteranodon beds is occupied by a bed of shales with a thin bed of limestone. The beds are wanting in the Iowa-Nebraska and eastern Dakota areas. In the following table, which is intended to show the relation of the different subdivisions in the representative areas, the eastern Dakota area is omitted, as it does not differ materially from the Iowa-Nebraska.

<table>
<tr><th></th><th></th><th colspan="2">Kansas area</th><th colspan="2">Colorado area</th><th>Black Hills area</th><th>Iowa-Nebraska area</th></tr>
<tr><td rowspan="7">THE COLORADO FORMATION</td><td rowspan="3">NIOBRARA SERIES</td><td rowspan="2">Pteranodon beds, 275′</td><td>Hesperonis beds, 150′</td><td colspan="2">Apishapa beds, 200′</td><td>Shale, limestone, 150′</td><td>Wanting</td></tr>
<tr><td>Rudistes beds, 125′</td><td colspan="2">Upper Timpas, 125′</td><td>Shale, limestone, 200′</td><td>Wanting</td></tr>
<tr><td colspan="2">Fort Hays limestone, 50′ to 60′</td><td colspan="2">Lower Timpas, 50′</td><td>Limestone, 2′ to 4′</td><td>Chalk, limestone, 40′</td></tr>
<tr><td rowspan="4">BENTON SERIES</td><td rowspan="2">Shale group, 250′</td><td>Blue Hill shales, 100′</td><td rowspan="2">Carlile shale, 200′</td><td>Upper Carlile</td><td>Shale, 30′ to 40′</td><td>Wanting</td></tr>
<tr><td>Ostrea shales, 150′</td><td>Lower Carlile</td><td>Shale, 20′ to 30′</td><td>Wanting</td></tr>
<tr><td colspan="2">Limestone group, 40′ to 50′</td><td colspan="2">Greenhorn limestone, 25′ to 40′</td><td>Limestone, 10′ to 15′</td><td>Wanting (?)</td></tr>
<tr><td colspan="2">Bituminous shale, 20′ to 40′</td><td colspan="2">Graneros shale, 200′</td><td>Shales, 100′</td><td>Shales, 40′</td></tr>
</table>

W. N. LOGAN.

EDITORIAL

THE December number of the *Astrophysical Journal* gives a translation of a paper "On the Constitution of Gaseous Celestial Bodies," by A. Ritter, which possesses much geological significance if its general conclusions are trustworthy. The original paper is one of a series of eighteen which appeared between the years 1878 and 1883 in Wiedemann's *Annalen*, but its astronomical and geological bearings appear to have escaped the attention they merit, and for this reason it is now reproduced. Ritter attempts to compute the time which would be occupied by a gaseous solar sphere of the dimensions of the earth's orbit in contracting to the dimensions of the present sun; in other words, the time of evolution of the solar system from the separation of the earth to the present stage under the Laplacean hypothesis, with certain qualifications. The computation is necessarily based on certain assumptions, some of which require modification in the light of more recent investigations, but any competent attempt at a mathematical discussion of the rate of solar evolution under the gaseous hypothesis constitutes a notable contribution to the cosmical phases of geology. The conclusion is reached that about 5,500,000 years ago the solar radius was equal to the radius of the earth's orbit. On the assumption that the effective radiating disk of the sphere was always equal to the whole disk, Ritter concludes that the solar mass shrank from dimensions of the earth's orbit to a dimension ten times the present sun's diameter in the remarkably short period of 255,710 years. On the assumption that the effective radiating disk was half of the whole disk, he finds that a similar shrinkage would take 511,420 years. In the latter case the total time occupied by the solar mass in contracting from the earth's orbit to its present dimensions would be about 5,765,000 years. This con-

clusion is based on the assumption that the thermal capacity was 1.41. On the assumption that it was five thirds, which is the largest permitted by the mechanical theory of heat, the conclusion is reached that the contraction could at most have occupied about 6,500,000 years.

The foregoing computations are based upon Pouillet's estimate of the present radiation of the sun. If the computation be based on recent estimates, which give a rate at least 50 per cent. greater, the resulting time is about 4,336,000 years. Ritter recognizes that the departure of the body from a spherical shape arising from rotation would modify the results, as these were based on the assumption of a spherical form throughout the whole period, but as this departure was large only during the comparatively small portion of the whole interval occupied in the contraction from the earth's orbit to twice the sun's present diameter, the correction is limited, but yet may be considerable. In view of this the author remarks: "For these reasons we cannot give the maximum value $t = 4{,}336{,}000$ years found above the significance of a superior limit for the age of the earth, the less in fact since the original assumptions must still be regarded as hypotheses imperfectly satisfied. Nevertheless it seems permissible to conclude from the above investigation that the actual age of the earth must be far less than the estimates of some geologists, who place it at hundreds of millions of years."

Whatever corrections may be applicable to such a computation, the attempt to subject the time factor of the gaseous hypothesis of the evolution of the solar system to rigorous mathematical inquiry is a most helpful one. The discussions of Lord Kelvin and others who have attempted to assign limits to the age of the earth by merely determining the maximum amount of heat which the sun can have radiated in the past, on the gravitational hypothesis, do not really get home to the question, since they do not determine the rate of radiation of heat in the past. If that rate were faster than the present rate it is obvious that the time would be correspondingly shortened; if

slower, it would be correspondingly lengthened. This radical defect is obviated, in the main, by Ritter's method.

If the period occupied by the supposed gaseous ancestor of the sun in shrinking from the earth's orbit to its present size is such as computed by Ritter, or if it be any period of that order of magnitude, it will probably be the conclusion of geologists and biologists that the hypothesis of such a gaseous sun is irreconcilable with geological evidence and with the phenomena of biological evolution. At any rate, this is a mode of testing the validity of the gaseous hypothesis which merits the careful consideration of those competent to pass judgment upon it, and it is earnestly to be hoped that the method of Ritter and his assumptions will be subjected to critical reëxamination in the light of the most recent researches.

The press announce that in a recent lecture before the Lowell Institute, Dr. See stated certain radical conclusions which he has reached with reference to the temperatures of the exteriors of gaseous bodies. We understand that his fundamental formula is closely analogous to one of those derived by Ritter. Applied to the sun when expanded to the dimensions of the earth's orbit, it gives a relatively low external temperature. It is not clear that this low outer temperature is compatible with the rapid loss of heat that appears to be involved necessarily in Ritter's rapid evolution, and we do not understand that Dr. See holds the latter view. Geologists will watch with interest the appearance of Dr. See's new views in authentic form, and may well congratulate themselves on the prospect of a discussion of the nebular hypothesis on new lines.

T. C. C

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The eleventh annual meeting of the Geological Society of America, which was held at Columbia University, in New York City, was characterized by a large attendance of the Fellows and by a very general interest in the proceedings. The accommoda tions furnished by the University were sumptuous in many ways the elegant Schermerhorn building proving highly satisfactory

except for the acoustic properties of the large lecture hall. The opportunities for luncheon were adequate and agreeable. The social features of the meeting, consisting of receptions at the American Museum of Natural History and at Professor Osborn's residence, and the annual dinner, were eminently successful. The dinner was pronounced the most satisfactory yet enjoyed by the society.

The program was varied and attractive, no one branch of the subject being greatly in excess of others. General geology, stratigraphy, physiography, glacial geology, palæontologic geology, and petrology were each represented by able exponents. But to those who attempted to follow the programs, it was evident that the shortness of the time devoted to the meetings, together with the length of the program of a well attended session, necessitate a better regulation of the proceedings than it has heretofore been the custom of the presiding officers to enforce. The evident hesitation on their part to interfere with the presentation of papers by Fellows of the society, while agreeable to the individual at the time, is not conducive to the best interests of the society as a whole, that is to say, to the other Fellows in general. Interference may properly be exercised in the case of those who exceed the time allotted them for the presentation of papers, especially since in most instances the time is that determined by themselves.

There should also be some rule limiting debate both as to length and matter. The exhibition of lantern views is a most valuable aid to the presentation of many subjects, which was very well shown at the meeting just held, but the selection of illustrations should be limited to those which actually illustrate the subject, and should be made to avoid unnecessary repetition.

The result of these abuses, the overrunning of time in presentation and discussion, and the introduction of unnecessary illustrations, is the crowding of papers on the last day of the meeting, the consequent haste in their delivery or the curtailing of considerable parts of them, and a general sense of dissatisfaction; first, with those who said too much, and last, with those

who said too little. The correction of these evils should rest with the presiding officers, but must originate with the Fellows themselves. It is to be hoped that some regulations will be formulated and put into operation at the next winter meeting in Washington, D. C.

J. P. I.

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IN an article on igneous intrusions in the October-November number of this JOURNAL, Professor Iddings states that, "Russell has called attention to what he considers volcanic plugs in the region of the Black Hills of South Dakota." I desire to deny the statement that the intrusions referred to were called *volcanic* plugs; abundant evidence was, I think, presented to show that they are, as I termed them, *plutonic* plugs. They are intrusions of igneous magmas forced upwards into horizontally stratified rocks so as to raise domes above them; but did not reach the surface, and hence should not be considered as occupying the conduits of volcanoes, and so far as can be judged, did not expand laterally after the manner of laccoliths. Not only one such intrusion was described, but several in various stages of exposure by erosion, from an unbroken dome of stratified beds, presumably with an intruded plug beneath, represented by Little Sun Dance Hill, to the imposing fluted column of Mato Tepee, over 600 feet high. Associated with these plug-like intrusions are what appear to be true laccoliths, as Warren Peak, for example. When this instructive region is more thoroughly explored, we may expect to find a series of examples illustrating the transition from plug-like to cistern-like intrusions or laccoliths. For these reasons it is well to hold the locality referred to, as furnishing the type-group of plutonic plugs.

The evidence just referred to was stated in the article[1] criticised by Iddings, but without having seen the intrusions and without presenting any new observations concerning them, he brushes it aside and restates the same kind of evidence for the

[1] Igneous intrusions in the neighborhood of the Black Hills of Dakota, JOUR. GEOL., Vol. IV, 1896, pp. 23–43.

apparent purpose of introducing a high-sounding Greek name in place of the term used by me.

In discarding the evidence of the plug-like character of the intrusions near the Black Hills, Iddings states that it is probable they are central remnants of small laccoliths, for the reason that the prismatic columns of which they are largely composed are vertical, "whereas they should be horizontal in the body of a volcanic plug." Unfortunately for this dictum, the prisms in many true volcanic plugs or necks, like those about Mt. Taylor, New Mexico, described by Dutton, are vertical.

In the same spirit in which Iddings discards the evidence of the plug-like form of the intrusions under consideration, and with equal justice, one might use his own language in reference to the account he himself gives of Mt. Holmes, the new type-example brought forward and of the accompanying, largely ideal diagram; "He has mentioned nothing that demonstrates or even indicates that it possesses the character of a plug;" it might just as well be a laccolith eroded down to the feeding conduit.

The term *bysmalith* which Iddings seeks to substitute for plutonic plug, means simply plug-stone, and may be used with equal propriety for both volcanic and plutonic intrusions, of plug-like form; if one wishes to make this convenient distinction the terms *volcanic bysmalith* and *plutonic bysmalith* would have to be used. I fail to see any advantage in such a clumsy nomenclature. The word bysmalith is so similar to *bathylith*, already in the field and also used by Iddings in the article referred to, that confusion must arise if this rechristening is permitted. It seems to me that American geologists should use their mother tongue whenever it can be made to serve, and usually it will be found rich enough to express all the ideas they may have, instead of searching the dictionaries of the dead languages for more or less accurate translations of plain English terms.

ISRAEL C. RUSSELL.

[The use of the term volcanic instead of plutonic in referring to the intrusions in question was inadvertent; much of the assumed distinction in the use

of the terms being artificial and misleading, the writer has become indifferent in his use of both terms.

Nevertheless, with regard to what Professor Russell has called plutonic plugs in the Black Hills region, it may still be said that "In his description of them he has mentioned nothing that demonstrates or even indicates that they possess the character of a plug. In each case they may be central remnants of small laccoliths."

The question, whether the evidence regarding the nature of the Holmes bysmalith is of the same kind as that offered for the character of the Black Hills intrusions, may very well be referred to our fellow-geologist. J. P. I.]

Reviews.

Fossil Medusæ. By C. D. Walcott. Monog. U. S. Geol. Survey, Vol. XXX, pp. 1–201, Plates I–XLVII, Washington, 1898.

This monograph of the fossil medusæ of the world, is the outcome of a careful study of some 9000 specimens of these organisms from the Middle Cambrian shales of the Coosa valley, Alabama. It was the author's first intention to include his observations upon these fossils in a work upon the Middle Cambrian fauna, but as the fossil medusæ from other geologic horizons and from other parts of the world became involved in the investigation, the present monograph was prepared.

Notwithstanding the evanescent character of these jelly-like organisms, their fossil remains have been preserved in the Lower Cambrian strata of New York and several European localities, in the Middle Cambrian of Alabama, in the Permian of Saxony, and the Jurassic of Bavaria. The Alabama specimens occur as more or less radiately lobed, semi-cherty nodules which weather out from the shales in great numbers.

A new family, *Brooksellidæ*, is founded for the reception of the genera *Brooksella* and *Laotira* from Alabama and *Dactyloidites*, previously described from the Lower Cambrian of New York. Two species of *Brooksella* and one of *Laotira* are described, and the one species of *Dactyloidites* is redescribed, and it is surprising that the details of structure of these ancient "jelly-fish" can be so fully determined. The generic term *Medusina* is used for the designation of all those fossil Medusæ whose true generic relations cannot be fully determined, and in this group are placed the three Cambrian species from Sweden. Some observations are made upon the genus *Eophyton* in which have been placed various trails which may have been produced by the tentacles of floating medusæ dragging upon the mud of the sea bottom, or by floating seaweeds. The remaining pages of the volume are devoted to the descriptions of the European Permian and Jurassic forms.

Stuart Weller.

The University Geological Survey of Kansas. Vol. IV. Paleontology. Part I. Upper Cretaceous. SAMUEL W. WILLISTON, Paleontologist. Topeka, 1898.

It is with much interest that we examine this work on the paleontology of Kansas. Professor Williston and his associates have made a successful effort to produce a work of popular as well as scientific value. The effort is worthy of commendation. The manner in which the subjects are presented cannot fail to make the book useful in many places where a purely scientific work would be of little value.

Professor Williston reviews the work on Birds, Dinosaurs, and Crocodiles; but the most interesting and instructive part of his work is the monograph on the Mosasaurs. While his work is primarily with the Kansas Mosasaurs, he does not confine his study to these, but briefly and concisely covers the whole subject. Here, especially, he has been successful in keeping the interest alive.

The monograph opens with a brief historical summary of the Mosasaurs — their discovery and the publications concerning them. This is followed by their range, distribution, and classification. He refers to the controversies over the relations of these reptiles, and arrives at the conclusion from his own study, that they are entitled to be classed as "an independent group among the *Lacertilia*." In this connection he quotes the classification proposed by Dr. Baur. The greater part of the monograph is devoted to a careful anatomical comparison and description of these interesting reptiles, many of which the author originally discovered and described. No pains have been spared to make the work complete and useful.

In his systematic descriptions Professor Williston points out a number of facts of popular, as well as scientific interest. The Mosasaurs are described as "varying in length between five and forty feet," a decided reduction in size from the Mosasaurs of the text-books, which are given a maximum length of 100 feet. Another fact which seems to have escaped the notice of former collectors is the deformation of the bones undergone in the process of fossilization, especially in the Niobrara formation. The bones have yielded as if made of plastic material. The deformation has furnished the characters upon which many new species have been based. The author concludes that this will cut out about four fifths of the species that have hitherto been described.

The turtles are described by Professor Williston and Professor E. C. Case, and the microscopic organisms by C. E. McClung.

Mr. W. N. Logan who has done much toward giving us a clear conception of the stratigraphic relations of the Upper Cretaceous, presents an excellent discussion of the invertebrates of the Benton, Niobrara, and Fort Pierre groups. He not only reviews the species hitherto described, but adds the descriptions of many new ones which he has found. His work is admirably arranged, and the species so tabulated, that the whole forms a convenient paper of reference. It is to be hoped that much more work of this kind may soon be done in the great Interior Cretaceous region, that a more definite knowledge of its rich invertebrate fauna may be available.

W. T. LEE.

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THE PETROGRAPHICAL PROVINCE OF ESSEX COUNTY, MASS. III

ROCKS OCCURRING IN DIKES

The rocks described in the preceding part of this article are cut by numerous dikes of various kinds, ranging from very acid aplites to basic diabases. The last are, as is usual along the Atlantic border, the most numerous; aplites and acid granite-porphyries come next, and finally there is a smaller number of rare and interesting types of alkali-rich dike rocks. These have not yet been fully investigated, but, as the rather large number of specimens in my possession represent apparently the main types, a description of them will give at least an approximate idea of the intrusive rocks of Essex county.

GRANITIC DIKES

Aplite.—Dikes of this rock are confined almost exclusively to the granite areas, at least as far as my observations permit me to judge. They are usually very narrow, only a few inches in thickness, and contact phenomena are not very conspicuous.

Megascopically they are dense and fine-grained, of various shades of light gray, and often showing a few small biotites. In thin section they show no very remarkable peculiarities, being a holocrystalline mass of small anhedra of quartz and alkali-feldspar, the latter usually microperthitic. Micrographic inter-

growths of feldspar and quartz are rather common. Colored components are rare, those most often met with being olive-green hornblende and brown biotite, while colorless diopside is less frequent. A few specimens carry titanite and magnetite, while apatite is seldom seen. These aplites are occasionally coarser-grained, and become microgranites, when they resemble closely the granites proper, except that the crystallization is on a smaller scale, and colored minerals are rare.

The most interesting aplitic dike found is one cutting a granite exposure near Bass Rocks, Gloucester. It is the same mass as that mentioned previously with enclosures of orbicular syenite and diorite, and the aplite cuts granite and enclosures impartially. The dike is only 6–7 cm wide, and is notable on account of being compound in an anomalous way. The borders, about 2 cm on each side, are of fine-grained white microgranite speckled with small, black biotite and hornblende flakes. This shows under the microscope the usual micrograniitic structure and characters. Extending down the center is a band, about 2 cm in width, of a dense, almost aphanitic light gray aplite, which shows under a lens only very minute black specks. This in thin section is a very finely granular aggregate of round quartz and alkali-feldspar anhedra, with here and there small shreds of green hornblende and pale brown biotite.

The junction between the two facies of the rock in the hand specimen is slightly irregular but sharp. Under the microscope it is also seen to be fairly sharp, but the quartzes and feldspars of the borders show a tendency to granularity and passage into the aplite which is suggestive of crystallization out of one magma and not that due to two injections. This idea of differing crystallization in one magma is also supported by the uniformity with which the aplitic band sustains its central symmetrical position with reference to the two sides. The highly anomalous character of the dike will have been noticed, in that the borders, contrary to the usual rule, are more coarsely crystalline than the central portion. If we adopt Judd's[1] view of the composite dikes

[1] J. W. Judd, Q. J. Geol. Soc., Vol. XLIX, p. 536, 1893.

of Arran it is easy to explain this by assuming that the first-formed dike cracked down its center, and that this crack was filled by a later injection, which, cooling rapidly, solidified as aplite. This is not the place to enter into a discussion of the subject, but it may be said that in view of the facts noted above, the similarity in chemical composition of the two portions, and for other reasons, this explanation does not seem to be the correct one, and we are forced to conclude that the dike is due to only one injection. In this case the coarser crystallization at the borders may be due, as Professor Iddings has suggested to me, to the presence of mineralizers derived from the surrounding granite, or, as seems to me more probable, to certain peculiar physical and chemical conditions which I hope to explain in another place.

	I	II	III	IV
SiO_2	77.49	76.44	77.14	77.61
TiO_2	0.25	0.37	0.29	0.25
Al_2O_3	11.89	12.95	12.24	11.94
Fe_2O_3	0.34	0.19	0.29	0.55
FeO	1.12	0.89	1.04	0.87
MnO	trace	trace	trace	trace
MgO	0.09	trace	0.06	trace
CaO	0.45	0.15	0.35	0.31
Na_2O	4.58	4.76	4.64	3.80
K_2O	4.26	4.95	4.47	4.98
H_2O (110°)	....	....	....	trace
H_2O (ignit.)	0.16	0.09	0.14	0.23
	100.63	100.79	100.66	100.54

I. Aplite. Border of Dike. Bass Rocks. H. S. Washington anal.
II. Aplite. Center of Dike. Bass Rocks. H. S. Washington anal.
III. Aplite. Composition of whole dike, two parts of I, one part of II.
IV. Granite. Rockport. H. S. Washington anal. JOUR. GEOL., VI, p. 793, 1898.

Analyses were made both of the border and of the center and are given above in I and II. The composition of the dike as a whole, calculated from two parts of I and one part of II, is given in III. The two parts of the dike are seen to be sensibly identical in composition, the border with a little more silica, lime and magnesia, and a little less alumina and alkalies. The

composition of the dike as a whole is remarkably similar to that of the granite of the region (analysis IV), the only noteworthy difference being in the soda.

Quartz-syenite-porphyry.—Dikes of this are met with in considerable numbers in the granite areas, especially that of Cape Ann, where they have been mapped by Shaler.[1] The best specimens in my possession come from the dikes numbered by Shaler 52, 53, and 70 on Eastern Point, and 245, a short distance north of Squam Light, the last being the freshest. Megascopically they show phenocrysts of alkali-feldspar, hornblende and biotite, and fewer of quartz; scattered through a fine-grained groundmass composed of feldspar, some quartz and specks of ferromagnesian minerals. The specimen from near Squam Light is a rather dark ash-gray, while the others are brownish-gray.

Under the microscope the large feldspars are seen to be microperthitic and are all cloudy and somewhat decomposed. The large hornblendes are ragged in outline and usually slightly altered, brown limonitic flakes being seen at their edges. They are of a peculiar, rather vivid grass-green, resembling that of actinolite, and are quite pleochroic. A few ragged plates of greenish-brown biotite are seen as phenocrysts. The groundmass is granitic and holocrystalline, the quartzes clear and generally interstitial between the feldspars. These are almost entirely of orthoclase or soda-orthoclase, not usually microperthitic, with a few doubtful oligoclases. They show a marked tendency to automorphic development. Irregular shreds of hornblende and biotite, similar to those forming the phenocrysts, are quite common, the former being the more abundant. A few small grains of magnetite and titanite are seen here and there and minute needles of apatite are fairly common.

For analysis the freshest specimen from Dike 245, north of Squam Light, was chosen, the result being given below, with that of the Wolf Hill nordmarkite for comparison.

[1] SHALER, Ninth Ann. Rep. U. S. Geol. Surv. Plate LXXVII.

	I	II	III
SiO_2	68.88	68.36	69.00
TiO_2	trace	trace	0.35
Al_2O_3	14.96	16.58	13.95
Fe_2O_3	0.64	0.90	1.56
FeO	4.64	3.24	2.38
MnO	trace	trace	0.55
MgO	0.37	0.45	0.14
CaO	1.74	1.85	0.49
Na_2O	3.83	3.97	5.67
K_2O	4.97	5.27	5.11
H_2O (110°)	0.06	0.18	....
H_2O (ignit.)	0.24	0.17	0.70
	100.33	100.97	99.95

I. Quartz-Syenite-Porphyry. Squam Light. H. S. Washington anal.

II. Nordmarkite. Wolf Hill, Gloucester. H. S. Washington anal. JOUR GEOL., VI. p. 800, 1898.

III. Lindoite. Frön, Norway. V. Schmelck anal. Brögger: Eruptivgest. des Krist. geb. I, p. 139, 1894.

The composition is rather acid, with high alkalies and rather high lime, with ferrous oxide largely in excess over ferric, and is closely similar to that of the nordmarkite. These dikes resemble in certain ways the lindoites of Brögger, which are acid bostonitic rocks. This is seen from the chemical point of view by comparison of I and III, that of the Essex county rock differing materially only in the slightly higher lime. Mineralogically they also resemble each other closely, though blue arfvedsonite or riebeckite is common in the lindoites, while the hornblende here is a peculiar green with only a tinge of blue. One specimen of lindoite in my possession from Huk in the Christiania Fjord, collected under the guidance of Professor Brögger, shows greenish-brown hornblende with some biotite, and does not differ radically from the present dike rocks. Structurally also the two resemble each other, the groundmass feldspars being quite automorphic in stout tables, the quartz interstitial and the hornblende irregular.[1] We do not, however, find in our rocks the zircon which is so common in the Norway

[1] Cf. BRÖGGER, *op. cit.*, I, Fig. 15, p. 137.

rocks. These dike rocks might then with propriety be called lindoite, but in view of their more porphyritic character and for other reasons they will be referred to as quartz-syenite-porphyry.

In this connection must be described two rocks found cutting the gabbro at Nahant. The one, which occurs at Little Nahant, is fine-grained, scarcely porphyritic, mottled gray, pink and green, and is evidently considerably altered. It is essentially a hornblende-biotite-quartz-syenite, and resembles in most particulars the rocks just described. The feldspar is apparently mostly orthoclase, and the hornblende is of a similar peculiar green, not highly pleochroic, and much of it seems to be secondary. The biotite, which is primary and which occurs in smaller amount, is the most notable feature. It occurs as stout crystals with ragged edges, often partially altered to the green hornblende. Its color is greenish-brown, and the strong pleochroism is very striking and unusual; parallel to the cleavage deep grass-green, perpendicular to this reddish yellow-brown, the absorption in the former direction being much the stronger.

The second rock, which is found at the road-metal quarry at Nahant as narrow dikes and small "schlieren" in the gabbro, is a compact, almost aphanitic, rather dark gray rock without phenocrysts. In thin section it shows a multitude of small isodiametric crystals of biotite having a peculiar light yellowish color and usual absorption scheme. With these are very many small colorless diopside anhedra, which in parts of the slide become more numerous. These, together with many magnetite grains and some small apatite needles, are embedded in a colorless or slightly yellow mass, which between crossed nicols is seen to be composed of tabular orthoclase crystals with fewer of a twinned oligoclase, the mesostasis being in patches either alkali-feldspar or quartz, the latter less abundant. In places the feldspar mesostasis extinguishes simultaneously over large areas and becomes poikilitic in character, and in these areas automorphic feldspar crystals are wanting. The tabular feldspars are in fact best developed and sharpest when surrounded by interstitial quartz, when in feldspar they are much less well

defined and more uncertain in outline. The structure as a whole is a rather peculiar one. The rock would seem to be not very acid and with rather high potash, and its occurrence in connection with the gabbro (which it will be remembered also carries some orthoclase) is noteworthy.

A rock which is essentially an *alkali-syenite-porphyry* occurs as a dike on the southeast coast of Marblehead Neck cutting the rhyolite. It somewhat resembles a minette, though rather more acid. Hornblende is absent, diopside rare, and small stout crystals of biotite abundant. These are usually a peculiar light brown and pleochroic, but some are seen of a pale green, slightly bluish in tone, and with feeble pleochroism. This variety also occurs intergrown with the brown, and may be a bleached form of the latter, but it resembles closely the similarly colored biotite found in some of the granites, especially that of Marblehead Neck itself. The groundmass of alkali-feldspar is granular, much of it being decomposed with formation of kaolin. A few grains of probably secondary quartz are present.

PAISANITE-SÖLVSBERGITE-TINGUAITE SERIES

A small but very interesting group of dike rocks is distinguished mineralogically by the combination of alkali-feldspar and either glaucophane-riebeckite or aegirite. These carry abundant quartz at the acid end of the series (paisanite), little or no quartz in the intermediate members (sölvsbergite), and nepheline in the most basic (tinguaite). This series, it will be observed, corresponds very closely to Brögger's Grorudite-Sölvsbergite-Tinguaite series from the Christiania region.[1] As far as my observations go, these dikes are not very wide, a few feet at the most. Nearly all my specimens are from dikes cutting granite, either on Cape Ann or along the Manchester-Magnolia shore; one specimen only is from the foyaite area of Salem Harbor.

Paisanite.—The only example of this rock which I found is Shaler's dike No. 3, at the extreme southeast corner of Magnolia

[1] BRÖGGER, *op. cit.*, I.

Point, near the water's edge, which was called by him a quartz-porphyry, and was briefly described by Tarr. It has a width of ten feet, with a strike of N. 2° E. It is cut by a narrow dike of dense black diabase.

The rock is compact, with practically no change in texture throughout its width. Phenocrysts of white or yellowish alkali-feldspar, up to 1.5 cm. in diameter, and smaller smoky bipyramids of quartz are thickly sprinkled through a very fine-grained, rather dark blue-gray groundmass. By the action of the waves and the sea water, with which most of the dike is covered at high tide, the groundmass has been dissolved, and on these surfaces the beautifully sharp and automorphic phenocrysts of feldspar and quartz stand out prominently. The feldspars are stout, prismatic, parallel to the axis *a;* are frequently twinned according to the Carlsbad and also the Manebach laws, and show a number of planes. They will be examined crystallographically later.

Under the microscope the sections present a striking appearance. The sharp quartz phenocrysts are clear, with occasional streaks of minute gas or liquid inclusions, and not infrequently carry rounded inclusions of granular feldspar, or feldspar and glaucophane, like the groundmass; while here and there isolated crystals of glaucophane are also seen. The highly automorphic feldspars are uniformly microperthite, or microcline-microperthite, no plagioclase being seen. They are dusty with minute, often rod-shaped, microlites of a colorless transparent substance, the nature of which is difficult to determine, and are stained, especially at the edges, with limonite. They carry inclusions of glaucophane crystals, or small groundmass patches, which occasionally show a well-developed micrographic structure. There is little evidence of magmatic corrosion, especially in the feldspars, though the quartzes show a tendency to rounded angles and shallow embayments.

The groundmass is very fine-grained, and is composed of minute needles of dark greenish-blue hornblende, up to .01 mm. in length, strewn pellmell in a granular mass of feldspar and quartz. Neither magnetite nor apatite was seen, nor is any

glass present. Along the borders of the phenocrysts, both quartz and feldspar, the hornblende needles are smaller and crowded together, as if pushed aside by the growth of the large crystal, in a manner quite analogous to that described by Pirsson[1] in the case of a tinguaite from the Bearpaw Mountains. There is no evidence of flow structure in the proper sense of the term.

The hornblende is apparently a glaucophane-riebeckite, identical with that described elsewhere[2] in a sölvsbergite from Cape Ann. The extinction angle is small, pleochroism intense; parallel to the axes *c* and *b* dark blue-gray; parallel to axis *a* pale yellow. The position of the axes of elasticity could not be definitely determined, but apparently $\mathfrak{c}$ lies nearest to *c*, indicating that it is a glaucophane.

An analysis of this rock is given below, together with one of the Texas paisanite and one of a grorudite from Norway. The paisanites were discovered by Osann as dikes in Transpecos, Tex., and named after the Paisano Pass, where the types were found. They are composed of quartz, alkali-feldspar, and riebeckite, in the Texas rocks this last forming blue spots in a white groundmass, and quartz and feldspar being also phenocrystic.

	I	II	III
SiO	76.49	73.35	74.35
TiO_2	trace	....	....
Al_2O_3	11.89	14.38	8.73
Fe_2O_3	1.16	1.96	5.84
FeO	1.56	0.34	1.00
MnO	trace	....	0.22
MgO	trace	0.09	0.07
CaO	0.14	0.26	0.45
Na_2O	4.03	4.33	4.51
K_2O	5.00	5.66	3.96
H_2O (110°)	0.12	....	....
H_2O (ignit.)	0.38	....	0.25
	100.57	100.37	99.38

I. Paisanite, Dike 3, Magnolia. H. S. Washington anal.

II. Paisanite, Mosquez Canyon, Transpecos, Texas. A. Osann. Tsch. Min. Pet. Mitth. XV, p. 439. 1895.

III. Grorudite, Varingskollen, Norway. Särnström anal. Brögger, *op. cit.*, I, p. 48, 1894.

[1] PIRSSON, Am. Jour. Sci. (4), II, p. 191, 1896.

[2] H. S. WASHINGTON, Am. Jour. Sci. (4), VI, p. 177, 1898.

The analyses of the two paisanites resemble each other closely, the main differences being in silica, alumina, and ferrous oxide. These rocks are analogous to the grorudites of Brögger, which, however, carry aegirite in place of soda-hornblende, and which are rather less acid than the Magnolia rock. The replacement of alumina by ferric oxide in the grorudite is to be noticed. The phenocrysts differ also in being alkali-feldspar, aegirite, and hornblende, while quartz occurs only in the groundmass, and the color of the rock is dark green, rather than blue, owing to the abundant aegirite.

Sölvsbergite.—The rocks belonging to this group are characterized by the presence of alkali-feldspar with aegirite or a soda-hornblende, with occasional biotite and very little or no quartz. In Norway the structure is generally trachytic, which is not the case in Essex county, but the similarity otherwise, both mineralogically and chemically, is so great that this structural difference may be overlooked.

The Essex county sölvsbergites are fine-grained and compact, not very porphyritic, and of a gray or blue-gray color. As the various dikes show rather diverse characters, they may be described separately.

One of these, from Dike 184, at Andrew's Point, Cape Ann, has already been described[1] as composed essentially of feldspar and glaucophane-riebeckite, with very little quartz. At that time, however, only sections from the border of the dike were available. Since then I have studied sections from the center as well with interesting results. The borders of the four-foot dike are very fine-grained and compact and of blue-gray color. At the center the rock becomes coarser, but is still fine-grained, and is composed of small black specks in a light gray groundmass.

Examining the sections under the microscope, it is seen that in the borders the hornblende is nearly constantly glaucophane, yet, as we approach the center, there are found streaks in which a bright grass-green aegirite partly replaces it. At the center the grain is larger, and the feldspars tend to become automor-

[1] H. S. Washington, Am. Jour. Sci. (4), VI, p. 176, 1898.

phic, the development being thick tabular, and a radiated arrangement quite common. The dark blue hornblende is present here in larger grains, but less abundant, while the green pleochroic aegirite, showing the usual characters is fully as abundant as it, and in places more so. The aegirite does not occur in needles, but mostly in stout, irregular anhedra, and only occasionally in rough prisms. Small crystals of a yellow-brown, highly pleochroic biotite are also seen. There are also numerous small, slender needles of a bright yellow pleochroic mineral, often arranged in stellate groups. Their pleochroism varies with the depth of their color, the deepest showing a reddish-yellow parallel to the length, and a lighter greenish-yellow perpendicular to this, while the paler ones show scarcely any pleochroism. These are the same which were thought to be either apatite or rosenbuschite in the former description, but here their larger size and more intense coloration permits of a better examination, and it seems that they are to be referred to astrophyllite.

A sölvsbergite of a somewhat different type is that forming Shaler's Dike 182, near Pigeon Cove, on Cape Ann. The dike itself is three to four feet wide, with strike N. 73° W. At one place a tongue of granite about ten feet in length protrudes into the dike. In this tongue, as well as immediately outside for a distance of twenty feet along the dike and a foot from it, the granite has been squeezed, and a gneissoid structure developed, the foliations on the outside bending around towards the tongue and being parallel to its length within it. Examined in thin section, the quartz and feldspars of this gneissoid granite are seen to have been squeezed, crushed, cracked, and frequently drawn out into lenticular shapes, exactly as in many gneisses. It is remarkable that such a squeezing should have taken place over such an extremely limited area, the granite outside of the gneissoid portion and on the other side of the dike being absolutely normal in character.

But to return to the dike. This is dark gray and compact, with a few small phenocrysts of aegirite and feldspar. In thin section, it is seen to be composed of a pale greenish hornblende,

pleochroic in light tints of blue-green and yellow-green, and with an extinction angle of 15°, partly in large, stout phenocrysts, but mostly as small, irregular grains, with small, stout flakes of a peculiar light brownish-gray biotite, embedded in microperthitic feldspar, generally in anhedra, but occasionally showing roughly tabular forms. Neither aegirite nor the normal blue hornblende is to be seen, nor was any quartz found.

A very pretty sölvsbergite forms Dike 55, which cuts the granite at the pier of the Hawthorne Inn, East Gloucester. The rock is aphanitic and chiefly a dull gray, but is mottled with streaks of white or greenish-gray, which run parallel to the walls. Under the microscope the only phenocrysts visible are a few sharply automorphic ones of alkali-feldspar, which are composed of orthoclase and albite, not arranged microperthitically, but forming aggregates of small granular anhedra. This structure seems to be due to secondary processes, as the rock is not quite fresh, and the sharp crystal outlines of the aggregates show that they were originally well-defined crystals. The groundmass is composed of a finely granular alkali-feldspar, possibly with a little quartz, thickly sprinkled with small blue or green needles. Most of these are of bluish-gray glaucophane, and are of two sizes. The smallest, usually less than .01 mm in length, tend to accumulate in rounded patches or streaks, surrounded by clearer feldspar carrying sparsely scattered, larger needles. Other streaks occur in the sections, corresponding to the pale streaks seen in the hand specimen, which are of feldspar carrying pale green aegirite needles and grains, with little, if any, glaucophane. In one place the orthoclase and albite are intergrown radially, forming sphaerocrystals which give a black cross between crossed nicols.

Another sölvsbergite, the specimen of which I owe to the kindness of Mr. Sears, occurs as a dike at West Cove, Coney Island, in Salem Harbor. This has been described by Rosenbusch, who calls it a bostonite-porphyry.[1] To a certain extent,

[1] ROSENBUSCH, Mikr. Phys., Vol. II, p. 425; also Elemente der Gesteinslehre, 1898, p. 198, where it is called "bostonitic alkali-syenite-porphyry."

my specimen agrees with his descriptions, especially as to the megascopical appearance, the feldspars and the flow structure. But there is a marked discrepancy in the colored components, and it is evident that here also the dike varies in character in different parts, assuming that the two specimens came from the same dike. From analogy with the Andrew's Point dike, it would seem that Rosenbusch's specimen came from the border, while mine came from near the center.

The rock is rather dark gray, fine-grained, and, in my specimen, with little suggestion of silky luster. The tabular alkali-feldspar phenocrysts are identical with those described by Rosenbusch. This author speaks of a blue glaucophane-like hornblende as the only colored component. In my specimen this occurs very sparingly, its place being taken by a highly pleochroic, peculiar olive-green hornblende, bright green aegirite grains, and flakes of a greenish-brown, intensely pleochroic biotite. Generally these are scattered uniformly through the section, but in places one or the other predominates. A few phenocrysts of colorless diopside are seen, surrounded by a narrow border of aegirite. A number of fair-sized titanite grains and a few apatite needles are present, but quartz is wanting. Flow-structure is very pronounced, and is well brought out between crossed nicols, on account of the highly tabular development of the groundmass feldspars.

The last of the sölvsbergites to be described was found as blocks in a wall along the back road southwest of Bass Rocks. It is very dense and compact and of a deep bluish-gray color. Under the microscope no phenocrysts are visible, and practically the only colored component is a deep blue glaucophane, which occurs in abundant needles or stout prisms. There are also present, in extremely small amount, small grains of colorless diopside, but no aegirite, biotite, or green hornblende. The rock is chiefly remarkable for its colorless base, which is composed of alkali-feldspar, with considerable quartz — enough to justify the name quartz-sölvsbergite. These are partly irregularly granular, but also form small patches with micro-

graphic texture, which are highly characteristic and very abundant.

The provenance of these blocks is not known, but they probably come from a dike in the immediate vicinity. Search revealed an outcrop of a dense, very pale gray dike, with only a slight tinge of blue, near a small pond across the road. This is evidently a bleached-out sölvsbergite, since the microscope reveals the fact that the small, originally blue, hornblendes are nearly all entirely decomposed to an opaque black substance, with little change of form, and small crystals of diopside are also possibly derived from them. This rock also shows the peculiar and striking micrographic patches, and it is therefore highly probable that the wall blocks were obtained from freshly blasted portions of this dike.

Only two analyses have been made by me of these rocks, which are given below. For comparison there are quoted an analysis of the Coney Island dike recently published by Rosenbusch, as well as two analyses of Norwegian sölvsbergites.

	I	II	III	IV	V
SiO_2	64.28	61.05	60.60	62.70	64.92
TiO_2	0.50	0.34	0.71	0.92	....
Al_2O_3	15.97	18.81	18.28	16.40	16.30
Fe_2O_3	2.91	2.02	2.85	3.34	3.62
FeO	3.18	3.06	2.67	2.35	0.84
MnO	trace	trace	....	trace	0.40
MgO	0.03	0.42	0.52	0.79	0.22
CaO	0.85	1.30	0.99	0.95	1.20
BaO	none	none	....	....	....
Na_2O	7.28	6.56	6.66	7.13	6.62
K_2O	5.07	6.02	5.73	5.25	4.98
H_2O (Ignit.)	0.20	0.78	0.69	0.70	0.50
P_2O_5	0.08	....	0.15	....	....
	100.33	100.04	99.85	100.53	99.60

I. Sölvsbergite. Dike 184, Andrew's Point, Cape Ann. H. S. Washington anal. Amer. Jour. Sci., (4) VI, p. 178, 1898.

II. Sölvsbergite. Dike. Coney Island, Salem Harbor. H. S. Washington anal.

III. Sölvsbergite ("Bostonitic Alkali-syenite-Porphyry"). Coney Island. M. Dittrich anal. Rosenbusch, Elem. d. Gest. lehre., 1898, p. 199, No. 3.

IV. Katoforite-Sölvsbergite. Lougenthal, Norway. L. Schmelck anal. Brögger, *op. cit.*, I, p. 80.

V. Aegirite-Sölvsbergite. Sölvsberget, Gran, Norway. L. Schmelck anal. Brögger, *op. cit.*, p. 78.

The Andrew's Point sölvsbergite is rather acid and approaches closely the katoforite-sölvsbergite from the Lougenthal. It resembles the Coney Island dike in its main features, especially in the high alkalies and the relations of the iron oxides. The two analyses of the Coney Island dike resemble each other very satisfactorily, and show that it is rather more basic, approaching the Kjöse-Aklungen dike, which, however contains a little nepheline. It is evident from these analyses and the descriptions given that the Coney Island rock is really a sölvsbergite and not a bostonite-porphyry, for which indeed, as Rosenbusch himself remarks, it carries an abnormally large amount of colored minerals.

Tinguaite.— The most basic members of the series we are now discussing, the tinguaites, which are not abundant in Norway, occur very sparingly in Essex county, only three dikes of this rock having come to my notice.

One of them, an analcite-tinguaite, from Pickard's Point near Manchester, has been already described.[1] It is aphanitic and olive-green, with only rare phenocrysts of feldspar in a groundmass of aegirite needles, alkali-feldspar, nepheline and analcite. The perfect freshness of the rock, as well as theoretical considerations, lead to the conclusion that the analcite is primary.

The second tinguaite occurrence is that recently described by Dr. A. S. Eakle[2] as a biotite-tinguaite from Gale's Point near Manchester. It is composed of alkali-feldspar, nepheline, kaolin and secondary quartz, aegirite, and a little biotite and magnetite. As Dr. Eakle points out it approaches the nepheline-bearing sölvsbergite from Kjöse-Aklungen already mentioned, and might be classed with the sölvsbergites.

The third occurrence of tinguaite is a dike two hundred yards east of Squam Light, discovered by Mr. Sears, to whom I am indebted for a specimen, The rock is dark green and very dense. This is also a biotite-tinguaite and very fresh. No phenocrysts are visible. Abundant small irregular grains and

[1] H. S. Washington, Am. Jour. Sci., (4), VI. p. 182, 1898.

[2] A. S. Eakle, Am. Jour. Sci., (4), VI, p. 489, 1898.

prismatic crystals of aegirite with fewer small flakes of brown biotite, are strewn in a colorless base composed of small tabular alkali-feldspars with interstitial nepheline. Colorless needles of what is probably diopside are also present, but no magnetite was seen. The rock shows a well marked flow structure.

Of these rocks we have two analyses, both already published, one of the Pickard's Point analcite-tinguaite, the other of the biotite-tinguaite. With them are given for comparison analyses of the border and center of the Hedrum tinguaite dike and the Kjöse-Aklungen sölvsbergite.

	I	II	III	IV	V	VI
SiO_2 -	56.75	60.05	56.58	55.65	58.90	54.22
TiO_2 - -	0.30	0.11	....	....	0.40	0.38
Al_2O_3 -	20.69	19.97	19.89	20.06	17.70	20.20
Fe_2O_3 - -	3.52	4.32	3.18	3.45	3.94	2.35
FeO - -	0.59	1.04	0.56	1.25	2.37	1.02
MnO - -	trace	0.79	0.47	....	0.55	0.19
MgO -	0.11	0.23	0.13	0.78	0.54	0.29
CaO - -	0.37	0.91	1.10	1.45	1.05	0.70
BaO -	none	....	....	....	....	trace
Na_2O - -	11.45	7.69	10.72	8.99	7.39	9.44
K_2O -	2.90	3.24	5.43	6.07	5.59	4.85
H_2O (110°)	0.04	0.15	....	....	....	0.42
H_2O (ignit) -	3.18	1.26	1.77	1.51	1.90	5.57
Cl - -	0.28	0.28	....	....	....	P_2O_5 0.11
	99.92	100.04	99.83	99.21	100.33	99.74

I. Analcite-Tinguaite, Pickard's Point. H. S. Washington anal. Trace of SO_3. Am. Jour. Sci. (4), VI, p. 185, 1898.

II. Biotite-Tinguaite, Gales Point. A. S. Eakle anal. Am. Jour. Sci. (4), VI, p. 491, 1898.

III. Tinguaite (dike border). Hedrum, Norway. G. Pajkull anal. Brögger, *op. cit.*, I, p. 113.

IV. Tinguaite (dike center). Hedrum. V. Schmelck anal. Brögger, *op. cit.*, p. 191.

V. Nepheline-Sölvsbergite. Kjöse Aklungen, Norway. V. Schmelck anal. Trace of P_2O_5. Brögger, *op. cit.*, p. 102.

VI. "Phonolite" (Tinguaite ?) H. N. Stokes anal. Southboro, Mass. Bull. 148. U. S. G. S., p. 77.

In I the only points which need be mentioned here are the rather low silica, high soda, and, for so fresh a rock, the high

content of water. It very closely resembles the Hedrum border rock, except in water and potash. The biotite-tinguaite is more acid, and closely corresponds in general features to the analysis of the Coney Island sölvsbergite. The characteristic distinction, however, is found in the relative amounts of the iron oxides and in the alkalies. In these respects the two tinguaite analyses resemble each other, and these two features, taken together, serve to differentiate their analyses from those of the more basic sölvsbergites. This whole series presents several points of interest, as regards the relations of the various members to each other, and their relative composition, but discussion of these features will be deferred to a later page. In connection with these rocks I may call attention to a so-called phonolite from Southboro, Mass., whose analysis is given in VI. Although not described an examination of sections of specimens kindly sent me by Professor B. K. Emerson proves that they are typical aegirite-tinguaites, one specimen showing very sharp nepheline crystals.

HENRY S. WASHINGTON.

(To be Continued)

THE DISTRIBUTION OF LOESS FOSSILS

It has perhaps been noted that the loess molluscs thus far reported in the literature of the subject are, for the most part, from localities in close proximity to the larger streams. This fact may have suggested the thought to those unfamiliar with the modern habits and present distribution of these molluscs that the adjacent streams had in some way something to do with the entombing of the shells now found in the loess. That the loess is most richly fossiliferous near streams is generally, though not always, true. The abundance of fossils is a decidedly variable quantity. There are exposures near streams which exhibit fossils in profusion, and others which are wholly barren. On the other hand, exposures quite remote from streams contain fossils —though in such situations a proportionately much larger part of the loess is entirely devoid of them.

This fact has sometimes led geologists to attempt to distinguish, in varying degrees, between the loess adjacent to streams and loess more remote. Whatsoever distinction may be observed in the physical characters of the loess of various deposits,[1] no distinction can be based on the presence or absence of fossils alone. The simple fact that one deposit is fossiliferous and another is not, does not prove, nor even indicate, that the deposits were formed under wholly, or even materially different circumstances. In the one case there are no fossils simply because there were no shells to be buried; in the other, fossils are common because shells were abundant on the old land surfaces, where they were covered as other imperishable objects would have been covered.

Fossils are more abundant in the vicinity of streams because

[1] For one of the most recent discussions of the loess with reference to its variation according to distance from streams, see Dr. Chamberlin's article in the Jour. Geol., Vol. V, No. 8, p. 795.

the same species thrive, and in all probability did thrive in the past, in just such situations.

Manifestly, if we would judge of the conditions under which the fossils existed and were finally buried in the past, we must understand the conditions under which the same species exist today. It has already been pointed out by the writer[1] that the loess fauna of any section of the country closely resembles the modern molluscan fauna of the same section, the characteristic fossil species being for the most part characteristic species of the modern fauna. During the past summer the writer made more extended studies of fossils in widely separated loess regions, notably in Mississippi, Iowa (both eastern and western), and Nebraska, which strongly emphasize the foregoing fact. As questions of general geographical, as well as local, distribution of fossil and modern molluscs are of great importance in connection with any attempt at an explanation of the manner in which loess was deposited, the following remarks are offered as preliminary to further detailed reports upon the distribution of the loess species and of their modern representatives.

In Iowa and Nebraska, as elsewhere, the land shells form the characteristic fauna of the loess, and with two or three exceptions the same species may be found living within the borders of our state today.

The student who goes to the field to study the living forms in their natural environment, if his studies be sufficiently extended, will be struck by the many seeming eccentricities in distribution. He will, however, observe that our land molluscs as a rule favor the regions adjacent to streams — especially the rough, rugged hills which so often border them. This fact, however, seems to be dependent upon another, equally interesting and long well known — namely, that our timber areas for the most part skirt the streams — and that this distribution of vegetation determines largely the distribution of the molluscs is shown by the fact that the timber or brush-covered areas remote from streams are quite likely to yield plenty of shells. A few

[1] Proc. Iowa Acad. of Sciences, Vol. V, pp. 33, 41.

species (as for example *Succinea grosvenorii*) seem to favor open, rather grassy places, and a few others may be found among the weeds and bushes skirting prairie ponds, but as a rule rough, rolling timber areas are favored. Here an abundance of food (for nearly all are herbiverous) and more or less shade and protection are furnished by the vegetation. As we recede from the timber-bordered streams the number of species and specimens grows less, and the writer knows from personal experience obtained in various parts of the state that large prairie areas of that character may be searched in vain for any trace of a land mollusc. In the eastern part of the state, with its more rolling, timber-covered surface, almost every locality—certainly every county—presents numerous favorable locations for colonies of snails, but as the collector crosses the state westward he finds that in species and in specimens the molluscan fauna grows poorer, the timber-fringed streams or ponds and lakes alone marking the favorable localities.

If careful observations are made even in the best of these collecting grounds, whether in the eastern or western parts of the state, it will be found that much variation and inequality in local distribution exist. One hillside may present certain species, while the next, perhaps across a narrow ravine, will show a wholly different series, and a third near by may have none at all. A species which in one spot is the prevailing type, may, only a few rods or even feet away, be wholly or in part supplanted by another. This is sometimes due to differences in the abundance of trees and vegetation furnishing food, and to other variations in the character of the surface, but often it seems to be a mere accident.

The number of individuals of any, or all, species in a given locality is also very variable. In the most favorable spots, however, especially on higher grounds, one seldom finds many individuals together. Even such species as *Zonitoides arboreus*, *Z. minusculus*, *Vitrea hammonis*, *Cochlicopa lubrica*, *Succinea obliqua*, *S. avara*, etc., which may often be found in large numbers under leaves or sticks and logs in comparatively low places, usually show

fewer and more scattered specimens on hillsides, etc., especially in more open places. To get a good set of any species in such localities the collector must work over a considerable area, but in doing so he will almost invariably find individuals of several species mingled promiscuously. If he compares the molluscan faunas of the eastern and western parts of the state, he will find that, as stated, the number of species and individuals in the eastern part is, as a rule, greater. He will also find that there are certain rather striking differences between sets of some of the species taken at opposite extremities of the state. Those from the eastern part are likely to average larger in size and to be thinner shelled, resembling more nearly representatives from the eastern part of the country, while the western forms are smaller and heavier. This is especially true of *Polygyra mutilineata*, *Zonitoides minusculus*, *Succinea obliqua*, *S. avara*, and other species of the kind which are sometimes found in rather low places, but which also occur on higher grounds—especially westward. This is probably due chiefly to the scarcity of forests in the western and central parts of the state, where the rather scant groves usually consist of scattered and stunted trees, being quite different from the more vigorous forests of the eastern part. That this view is correct is further attested by the fact that the same species of molluscs, when occurring on comparatively barren or nearly treeless areas in the eastern part of the state, usually show the characters of the western types, namely, the smaller size and sometimes heavier, or at least more compact shell.

If the student will study the molluscs of a given region for a number of years, he will find that from year to year the abundance of the several species varies, some even running out entirely, while others unexpectedly appear. The writer has watched a number of localities near Iowa City for many years, and has found this variation often striking.

If, now, the distribution of the fossils in our loess is compared with that of the modern shells, a remarkable similarity is evident. The best collecting grounds are near streams, while the clay of the remote prairie is usually barren. Where fossils

are abundant one exposure contains species of one kind, another near by presents a new, or at least a different list, while still another has none—and the same variation which may be observed in the local distribution of the recent shells in any restricted locality, will be exhibited in individual exposures of fossiliferous loess.

In horizontal distribution the fossils show the same mode of distribution as that already noted in the modern forms. The specimens are not heaped together, but are scattered about like the modern shells, usually a number of species mingled together, but in unmodified loess invariably *not* crowded, so far as the writer's observations have gone.

The vertical distribution of the fossils also conforms to the surface distribution of the modern shells. If the loess was not deposited *in toto* at once, and this seems to be conceded, there were successive land surfaces upon portions of which shells grew. These shells varied from time to time in number, some persisted during long periods, some disappeared and others took their places. If we study the vertical distribution of the fossils in the loess the same variation in the succession of species is observed. Some species occur throughout the thickness of a particular exposure, but more frequently a part of the loess is without fossils, certain species occupy a part of the deposit, while above or below them are other species—as though the varying generations of surface species had been successively buried in the deposit. The number of specimens upon any one of the successive land surfaces was not very great even in richly fossiliferous loess, for if we draw lines approximately parallel to the present surface to represent the successive surfaces, we will find that in any one of them but few fossils occur.

Where depauperation or variation in size is noticeable in the fossils, it will be found that it takes place in the direction of the western modern forms. For example, while the common modern *Polygyra multilineata* at Iowa City is large, the common fossil form is small, though the small modern and the large fossil forms are also occasionally found, but not respectively with the

preceding forms. On the other hand, at Council Bluffs and Omaha the modern shells of this species are usually small, like those of the loess, though both fossil and modern shells of the large type occasionally occur. Thus the fossils of this species from the eastern part of the state resemble both the fossil and modern shells from the western part. *Succinea avara* is another example. The small typical form is common in the loess at Iowa City, but the modern shells are not frequent, occurring always on more or less wooded hillsides, while westward the type is the common modern form.

In the loess of both the east and the west,[1] *Sphyradium edentulum alticola*, *Pyramidula strigosa iowensis*,[2] *Succinea grosvenorii*, forms belonging now to the dry western plains, are quite common. Their presence, together with that of the "depauperate" forms, when considered in connection with the entire molluscan faunas of the eastern and western parts of the state, suggests a climate considerably drier than that of the eastern part of the state, and a surface less abundantly timbered. Certainly both modern and fossil faunas unmistakably show[3] that the conditions in the eastern and western parts of Iowa during the deposition of the loess were approximately included within the bounds of the present extremes presented by these regions, and that any attempt to drag into the discussion of this subject conditions either of a glacial climate or of frequent and widespread floods and inundations, or of any excess of moisture, is gratuitous.

The conditions which cause the depauperation of our shells exist more or less all over Iowa today, especially westward, and yet we do not have a glacial climate. If the molluscs

[1] The loess herein designated as "eastern" is that of eastern Iowa—the "western" being that of western Iowa and eastern Nebraska.

[2] This form has heretofore been reported as var. *cooperi* which lives abundantly in the far West, but Pilsbry regarded it as extinct and distinct, and has described it under the name *iowensis*. All living forms of *strigosa* belong to the high, dry regions of the West. Neither of these species was found at Council Bluffs, but both are found in the loess of Nebraska. *Sphyradium* was formerly included in *Pupa*.

[3] See also the writer's paper in Proc. Ia. Acad. Sci., Vol. V.—particularly p. 42.

of the loess be used as an absolute measure of the amount of moisture occurring during loess times, then we must conclude that Iowa was without streams, for practically no fluviatile molluscs occur in the loess, and that there were but few ponds in which aquatic molluscs found a favorable habitat, for even aquatic Pulmonates are rare in the loess,[1] the number of terrestrial forms being out of all proportion to that of the aquatic forms.

During the past summer the writer collected several thousand specimens in the loess of Mississippi and western Iowa, and among them all there were not a half dozen aquatic shells. A list of the modern shells of Iowa shows a large number of aquatic species, yet few of these occur in the loess. There is also among the modern terrestrial forms a large number of those which occur only in very damp places—and these, too, are almost wholly missing from the loess. The writer is well aware that many of the forms found in the loess are often referred to as aquatic or "semi-aquatic," or at least as favoring very wet situations. But evidence of this character has been furnished largely by those who are familiar only with the molluscan fauna of the eastern part of the country, where the amount of rainfall is much greater, and where surface conditions are not the same as in Iowa and Nebraska—or it has come from so-called "closet-naturalists." Now, the "closet-naturalist" has done abundant harm in this as in other branches of science. Too remote, often, from the phenomena under discussion, or too dainty to soil his fingers with the toil and the exposure of field-work, he has passed judgment upon the habits of forms which he knew only from material submitted by mail—or still worse, he has taken the work of others and, not appreciating the significance of the facts so borrowed, has distorted them to do menial service in the encouragement of some pet notion.

In the particular case in hand no distinction has been made between the habits of the depauperate varieties and the larger

[1] For more detailed comparisons see writer's paper (*loc. cit.*, pp. 43 and 44), and the discussion preceding.

types of the same species, and too often the habits of one species have been confused with those of another of the same genus, or even family, a mistake most frequently made with the Succineas. Again, the versatility of certain species—their adaptability to varying conditions—has been overlooked. *Zonitoides minusculus*, *Bifidaria pentodon*, *B. contracta*, *Succineaavara*, *S. obliqua*, etc., frequently occur in low places and then often in great numbers—but they are also found scattered over comparatively dry hillsides at considerable altitudes—and some of these species in such places develop the depauperate type, that is they average smaller in size. To show the preponderance of strictly terrestrial forms in the loess, the writer calls attention to the fact that in the collections made last June at Natchez and Vicksburg, Miss., numbering over forty species and nearly five thousand specimens, there is not a single aquatic form. Furthermore, every species which was collected in the loess of that region has been found by the writer, living upon the high bluffs and hills in and near Natchez, or upon hillsides at considerable elevations in other parts of the south, notably in northern Alabama, Georgia, and Tennessee.[1] At Natchez the most common living species is *Succinea grosvenorii*, and this crept upon the bare surface of the loess clay which, at the time of the writer's visit, had been baked by the hot summer sun of the south during a period of drouth lasting more than six weeks. Moreover, several scores of specimens which had been carried about in the sun all day long in a box containing loess dust, and hence were subjected to extremely desiccating conditions, were found, after this experience, creeping about in their prison seemingly perfectly contented. Yet we are sometimes told that the Succineas are all "semi-aquatic," or that they must have an abundance of moisture. Another illustration, equally striking, is furnished by the writer's experiences and observations at Council

[1] It is also a significant fact that of all the living species found in the hills and bluffs of Natchez, only two, *Leucocheila fallax*, and *Polygyra texana*, were not found in the loess of that region. Only one specimen of the first and two of the second were collected. The former is not uncommon in the loess of the north, while the latter is not known from the loess, at least to the writer.

Bluffs during the past summer and autumn. It had been purposed to make a detailed comparative study of the fossil and modern molluscan faunas of that vicinity, but the work was somewhat interrupted by the severe September rainstorms and November blizzards. Nevertheless interesting and valuable data were obtained, and are here briefly presented.

More than four thousand fossils were collected, and their distribution was carefully noted in twenty exposures, beginning at the eastern extremity of 15th avenue in Council Bluffs, thence along the bluffs to the High School, a distance of about one mile, and in Fairmount Park, along its winding roads, for about half a mile eastward. The location of the several exposures is shown on the accompanying map. A list of the fossil species, together with the number of specimens collected in each exposure, is given in the appended table. If this table is studied it will be observed that of the thirty species collected not one is aquatic. For purposes of comparison the writer made collections of recent shells in seven distinct localities in practically the region containing the above-noted exposures. These localities are here discussed in detail, the letters designating them being also employed to mark them on the map.

a. A grassy, treeless hillside in Fairmount Park nearly opposite 11th avenue, and at an altitude of from 175 to 245 feet above the river valley.[1] Species 8, 11, and 29[2] were found living.

b. A grassy, treeless slope just above the exposure marked *N*. Altitude about 200 feet. Species 8, 10, 11, 15, and 29 were found.

c. Near the 10th avenue entrance to Fairmount Park, at an altitude of about 90 feet above the river plain, species 8, 10, 11, 21, 22, 27, and 30 were found. A few stunted and scattered bur oaks grow on the slope immediately above this point.

d. A brush-covered hill just above the exposure marked *E*.

[1] The altitudes were all determined by barometric measurements taken from the nearest north and south street on the river flat.

[2] The numbers refer to the species named in the table of fossils.

Altitude about 170 feet. A small collection containing species 11 and 30 was made.

e. A locality in the northwestern part of Fairmount Park on a northerly slope, somewhat grassy, but with shrubs and a few bur oaks, nearly opposite 8th avenue. Altitude 280 to 300 feet above the valley. Here were found species 3, 8, 11, 13, 18, 19, and 27, and also one specimen of *Bifidaria procera*, the only recent species found in the tract examined, which was not found in the loess. This locality is just over the brow, on the north or leeward side,[1] of one of the most exposed ridges in the area under consideration.

f. A part of the same slope immediately below *e*, and 50 to 100 feet lower. Here the forest is better developed and contains a number of species of trees. Species 8, 11, 18, 19, 22, 25, and 28 were found. The points *e* and *f* are on the same very steep slope, but *e* is much more exposed and drier, *f* being more protected by its forest covering and position. A comparison of the species from these points is therefore interesting. Species 3 and 13, while common at *e* were not found at *f*, the lower point. While 18 was common at *e*, only one specimen was found at *f*. No. 19 is also more common at *e* than at *f*. These facts are of interest when we seek to determine the extent to which shells are likely to be washed down even very steep slopes. Nos. 8 and 11 were about equally abundant, while Nos. 22, 25, and 28 were found only at *f*.

g. The banks and grassy slope near and above the exposure *M*. This yielded species 3, 13, 21, 24, and 27.

It will be observed that species 1, 2, 4, 5, 6, 7, 9, 12, 14, 15, 16, 17, 20, 23, and 26—or just one half the total number—are not contained in the collections of modern shells cited. The number of individuals of the surface species is also comparatively small. Of these numbers, 1, 16, and 23 are extinct in that section of the country, No. 1 occurring eastward, No. 16 westward, and No. 23 being entirely extinct.

[1] The prevailing winds during the seasons of the year when the snails are active, are from the southwest.

The modern fauna of the more or less exposed hills at Council Bluffs is much poorer in species and in specimens than the fossil fauna of the underlying loess, but every species thus far discovered in the loess of Council Bluffs occurs more or less abundantly (certainly as abundantly in some places as in any part of that loess) living along the Missouri River, especially on the western, more heavily timbered bluffs. All the species above mentioned as not found in the surface collections have been collected, by the writer, on the banks and hills along the Missouri between Omaha, Neb., and Hamburg, Iowa, usually not in very damp places, but living under the conditions which prevail along those bluffs. Even *Polygyra multilineata* is there often found on high grounds, and then appears as a stunted form like that which is common in the loess.

The loess fauna of Council Bluffs is thus not only wholly terrestrial, but, with the exceptions noted, is almost identical with the modern upland fauna of the same region—and surely no conditions of excessive moisture prevail in that region today. Yet a recent writer,[1] referring to the loess of the Missouri region, says: "In the Bluff loess more than nine tenths of the total number of individuals belong to species that are found only in unusually damp situations. . . . . The species having an optimum habitat that is not excessively moist have not been observed to occur abundantly in the Bluff loess."

Another interesting fact noticeable in the exposures of loess at Council Bluffs is the occurrence of the great majority of the fossils in a more or less distinct stratum which varies (so far as observed) in altitude from about 80 to at least 200 feet above the river valley, and which follows in general the contours of the present surface, but with a less convex curvature. In exposure *N* it seems to be a continuation of the shell-bearing layer in *E*, yet it is at least 100 feet higher. In exposure *M* it drops about 80 feet in a block. Its limits are not sharply defined above or below, and it varies in thickness from about 6 to at least 20 feet. Overlying it is a deposit of more or less

[1] C. R. Keyes, Am. Jour. of Science, Vol. VI, p. 304.

laminated loess clay, which is usually non-fossiliferous, and which varies from a few to more than 30 feet in thickness. When fossils occur in this upper stratum they are few in number and widely scattered.[1]

The presence of this shell-bearing stratum suggests that, for the period during which it formed the surface soil, and while it was slowly accumulating, the conditions in this particular locality were more favorable to the growth of land snails than now. There was probably more vegetation, and hence the surface was not so frequently storm-swept as at present. This does not necessarily signify that general climatic conditions were different, but that these particular banks or bluffs were more heavily timbered, with the Missouri River probably flowing at its base, its surface conditions being similar to those of many timbered hills and knolls between Omaha and Nebraska City west of the Missouri.

It is interesting to note that between Iowa and Nebraska the Missouri River now flows along the western side of its broad valley, and that the adjacent western bluffs are more heavily timbered and contain all the living species of molluscs herein recorded, with the exception of Nos. 1 and 16, while the more remote eastern bluffs are more barren and rugged. The shell-bearing band may simply represent the period during which the river in its shiftings occupied the eastern part of the valley.

The foregoing facts lend support to the æolian theory of the origin of the loess, as is shown by the following considerations.

1. The general manner of distribution of the modern and fossil molluscs is essentially the same, this fact indicating that they were not carried by waters, but were quietly buried in dust. Had they formed a part of river drift they would be more frequently heaped together, not scattered as we find them in the loess, and fluviatile shells would be more or less intermingled.

[1] At the base of the bluff, in exposure *K*, what seemed to be a second shell-bearing layer was observed about 75 feet below the main fossiliferous band. The section, however, was more or less obscured, and the mass may have slipped from the bluff above. The fossils in column *K* in the table are from this stratum. It will be observed that they are ordinary forms which are abundant in the main shell stratum.

Moreover in many years' experience in dredging in ponds and streams, the writer has seldom seen a land shell which had been carried with the finest sediment into ponds or lakes, though such shells are sometimes found in sand and other coarse material. Currents of water which could carry most of the shells now found fossil, would also carry coarser material than that which makes up the loess. Another fact which bears out this conclusion is the presence of opercula in fossil shells of *Helicina occulta* in the northern loess and *Helicina orbiculta* in the southern loess. As the operculum so readily falls from the decaying animal, it would scarcely remain in place if the shell had been transported any distance.

2. The occurrence of fossiliferous loess chiefly in the vicinity of streams is consistent with the theory of loess formation presented by the writer before the Iowa Academy of Science.[1] Plants, and especially forests, develop chiefly and primarily along streams. This creates conditions favorable to land molluscs, and at the same time forms a trap for the dust carried from adjacent more barren regions. The occurrence of loess in the eastern part of Iowa chiefly along the border of the Iowan drift sheet may also be explained on the same ground. After the melting of the ice the terminal moraines offered the first lodging place for plants. Here forests early developed, and the conditions for entrapping the dust from adjacent less favored territory which was probably dry during a part of the year were here first created. We are in the habit of describing the lobed ridges of loess regions as characteristic of loess topography, yet they are quite as much characteristic of some drift areas, as for example, along the Big Sioux River in Iowa and South Dakota. In eastern Iowa the surface of the loess is largely shaped by the underlying moraines which first presented conditions suitable to the deposition of the loess, and where consequently the deposit is best developed. The loess at Natchez does not show this loess topography in the same degree.

3. The depauperation of some forms of shells, and the pres-

[1] Proc. Iowa Acad. Sci., Vol. III, p. 82 *et seq.*

ence of others which are normally inhabitants of dry regions, suggest a climate sufficiently dry that during a part of the year at least, clouds of dust could be taken up by the winds.

4. The overwhelming preponderance of land snails in the loess must always be borne in mind. This however does not prove that the loess regions were entirely devoid of lakes and streams, but rather that the loess proper was deposited chiefly upon higher grounds, for, if by any agency fine material were to be uniformly deposited over all of Iowa today, covering the successive generations of our present molluscan fauna, there would be a much greater proportion of aquatic and moisture-loving species than we find anywhere in the loess.

5. The amount of material carried by the winds need not have been so great as is sometimes assumed. The estimate made by the writer[1] for the rate of deposition for eastern loess (1 mm per year), and that made by Keyes[2] for western loess ($\frac{1}{10}$ to $\frac{1}{4}$ of an inch), would be sufficient to form most of these deposits respectively in the 8000 years, usually computed, since the recession of the glaciers.

The objection made by Dr. Chamberlin[3] that "the æolian deposits are measured, not by the quantity of silt borne by the winds and lodged on the surface, but by the difference between such lodgment and the erosion of the surface," is met, at least in part, by the theory offered, for it is a well-known fact that timbered areas, even when very rough and with abrupt slopes, are scarcely eroded by even the most violent precipitation of moisture. Professor Udden's recent admirable report[4] also bears on this question, and should not be overlooked by the student of loess problems.

6. No distinction can be made between the origin of eastern and western loess. The finer quality and lesser thickness of the former rather suggest that there had been more moisture (*i. e.*,

[1] Proc. Iowa Acad. Sci., Vol. III, p. 88.

[2] Am. Jour. of Sci., Vol. VI, pp. 301, 302.

[3] JOUR. GEOL., Vol. V, p. 801.

[4] The Mechanical Composition of Wind Deposits, 1898.

a shorter dry period during each year), and hence less dust; that the winds were less violent, and that there were greater areas completely covered with vegetation, this resulting in the necessity of transporting dust much greater distances, which would therefore be finer.[1]

It should be borne in mind that the above-noted differences between the regions in question actually exist today. There is more rain, there are larger areas closely covered with vegetation, and less violent winds prevail, in eastern Iowa, and eastward, and considering the position of mountain chains and seas, the same differences must have existed for a long time. That they did exist during the deposition of the loess is also indicated by the proportionately somewhat larger number of species in the eastern loess, which prefer or require moist habitats. But the fauna of the eastern, or Mississippi River loess is essentially a terrestrial fauna. The great fluviatile groups now everywhere common in the streams of eastern Iowa are wanting in the loess, and the few fossil aquatic species are such as today prefer ponds, and are often found even in those which dry up during the summer.

It may again be emphasized that the fossils show no greater difference between the surface conditions which existed during the deposition of the loess of the eastern and the western parts of Iowa, than exists today between the surface conditions of the same regions. This fact is irrefutable, and must not be overlooked in any discussion of the conditions under which loess was deposited.

NOTES AND EXPLANATION OF MAP

[Scale, 8 in. to 1 mile]

The exposures are represented by heavy lines.

EXPOSURES *A*, *B*, and *C*

These were cut out of the same ridge in street grading. The shell-bearing stratum shows well on the east, south and west sides of *C*. It is about 12–15 feet thick. Above it there is a layer of clay about fifty feet thick and almost entirely devoid of fossils.

[1] See UDDEN, *loc. cit.*, pp. 56, 57 and 67.

TABLE OF SPECIES[1]

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1. *Helicina occulta* Say	5	55	210	5	5	81	17	89	9	14	3	12	14	96						
2. *Vallonia gracilicosta* Reinh.	10	157	12		1	8		21		3	1	1	1	45	1			1		
3. " *parvula* Sterki	2																		1	
4. " *perspectiva* Sterki	3	12																		
5. *Polygyra multilineata* (Say) Pils.		6	70	2		16	4	7		6	1		2	3	1		2		1	1
6. " *profunda*[2] (Say) Pils.																				
7. " *hirsuta*[3] (Say) Pils.	1																			
8. " *leai* (Ward) Pils.	4	21	63	1	1	17	2	14		4			1	12			2			
9. *Strobilops virgo* Pils.	8		3			2		1	1					1						
10. *Leucocheila fallax* (Say) Try.		2																		
11. *Bifidaria armifera* (Say) St.	35	280						3	1											
12. " *contracta* (Say) St.	5																			
13. " *holzingeri* (St.) St.								1												
14. " *curvidens* (Gld.) St.	1																			
15. " *pentodon* (Say) St.												2	4	12			2	3	2	
16. *Pupa blandi* (Morse) Binn.	11	127			1															
17. *Vertigo bollesiana* Morse												10	3	28						
18. *Cochlicopa lubrica* (Müll.) P. & J.	1	4	27	1	1	12		22	1	2				18						
19. *Vitrea hammonis* (Ström.) P. & J.	2	3	10			10	1	3			1	1		1						
20. " *indentata* (Say) P. & J.			1																	
21. *Conulus fulvus* (Drap.) Müll.						1		1	1				1	5						
22. *Zonitoides arboreus* (Say) St.	3	4	21			4	2	12						10			3			
23. " *shimekii*[4] (Pils.) P. & J.															2		1		2	
24. " *minusculus* (Binn.) P. & J.	1	2	6			1		3			1			7						
25. *Pyramidula alternata* (Say) Pils.		4	19		1	4	1	11	3	2				1						
26. " *striatella* (Anth.) Pils.	1	20	46	3		21		28	2		1	4	4	24	2			3	1	
27. *Helicodiscus lineatus* (Say) Morse	6	18	6		1	7		5						13						1
28. *Succinea obliqua*[5] Say } 29. " *grosvenorii* Lea }	3	180	935	8	10	235	58	279	8	72	21	12	5	250	4	2	15	3	15	3
30. " *avara* Say	15	11	16			7	1	11		2	1	3	2	14	4	2		3	5	
31. Egg of a land snail						1										1				

EXPOSURE *D*

The shell stratum is not so rich in fossils as in *C*. Above it there are 15–20 feet of clay in which a few Succineas were found. In the clay below the shell stratum there are several distinct but irregular bands of lime nodules—some very large.

EXPOSURE *E*

Very similar to *D*, but with only one band of nodules.

EXPOSURE *F*

Fossils are very abundant in the shell stratum, which can here be traced for 3 or 4 rods. The shell-less loess above is 8 or 10 feet thick.

EXPOSURES *G*, *H*, *I*, *J*, and *K*

These exposures were all formed from the same ridge by deep cutting and grading. The shell stratum is distinct in all of them, and, as in all the other sections, it follows in general the contour of the surface. It varies in thickness here from 6 to 20 feet. It is by no means equally fossiliferous throughout.

EXPOSURES *L* and *M*

These were formed by the grading of High School avenue. The street slopes westward from the High School, and drops about 60 feet in a block.

[1] The nomenclature of Pilsbry and Johnson's recent *Catalogue of the Land Shells of North America* is here employed. As there are some departures from former usage, the changes are here noted:

Species 2, 3, and 4 were formerly included under *V. pulchello*.

Species 5 and 6 were referred to the genus *Mesodon*, and 7 and 8 to *Slenotrema*.

Species 9 was included under *Strobila labyrinthica*.

The species of *Leuchochila* and *Bifidaria* were included in *Pupa*.

Species 18 was called *Ferussacia subcylindrica*.

Vitrea, *Conulus*, and *Zonitoides* were formerly placed in the genus *Zonites*, and No. 19 was called *Zonites radiatulus*.

Pyramidula was formerly *Patula*.

Species 29 was called *S. lineata*.

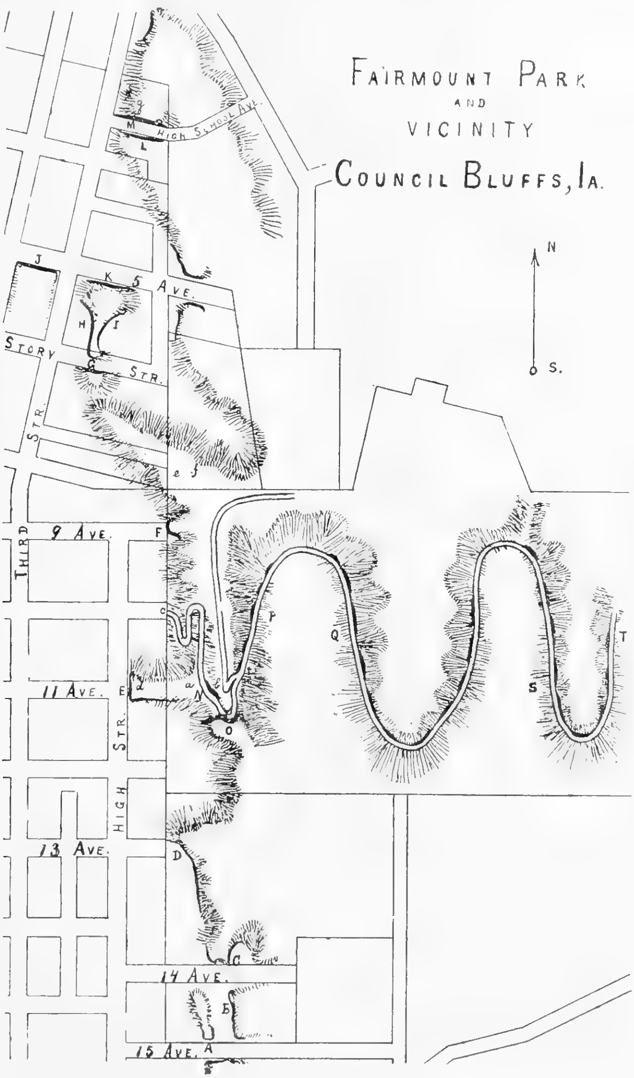
[2] One specimen of *P. profunda* was found by the writer in exposure C (since considerably altered) in 1890.

[3] Three specimens of this species were collected in exposure C in 1890.

[4] The writer formerly regarded this as a form of *Zon. nitidus*. Mr. Pilsbry, however, regards it as distinct, and in deference to his opinion his name is retained.

[5] The form of *S. obliqua* which occurs most commonly in the loess is the narrower, smaller form, with more extended spire, such as is not uncommon (living) in Iowa and as far east as Indiana. As it is difficult to distinguish between some forms of this and *S. grosvenorii*, the two species are not here separated, as more time for careful comparison of the large sets will be required.

On the north side the shell stratum is nearly parallel to the street grade, and but little above it. On the south side it dips below the street about half way down the slope.



EXPOSURES *N, O, P, Q, R, S,* and *T*

These are all exposures along the road which winds eastward from the 10th avenue entrance to Fairmount Park. At *N* the road is about 185

feet above the river valley, and the shell stratum (which is here very rich in fossils) extends about 3 feet higher. It dips down toward the west at such an angle that it would connect with the shell stratum at *E*, which is about 100 feet lower. The same layer may be traced more or less indistinctly to *O*, where there is a cut about 20 feet deep. The shell stratum rises to about 8 feet above the roadbed (here about 200 feet above the river valley), but fossils are not abundant. The remaining exposures along this road are formed by the road cutting the smaller, lateral lobes of the greater ridges. The letters apply to the extent of road from bend to bend, not to individual exposures. At the southern bends in the road are the high points, the road sloping down to near the bases of the ridges to the north.

Fossils are found in most of the little exposures (which in but few cases exceed 15 feet in height) along the road, but they are nowhere as abundant as in some of the exposures along the bluff fronts. The exposures which are represented on the map, but not lettered, are nonfossiliferous.

B. SHIMEK.

THE GRANITIC ROCKS OF THE SIERRA NEVADA[1]

THE higher part of the central Sierra Nevada and nearly the entire width of the southern Sierra consist of a granular complex to most of which the name granite is ordinarily applied. In the northern and central part of the range there are likewise numerous isolated granitic areas enclosed in rocks of other kinds. The rocks of the granular complex differ greatly in age and in chemical composition. The oldest rocks represented are gneisses. Some of these are probably recrystallized sediments, but the larger portion of them may be of igneous origin. While differing in origin these gneisses are a unit in that they have all undergone a thorough recrystallization under great pressure. While the associated granites may be in part responsible for this recrystallization it cannot be ascribed to contact metamorphism alone, for areas miles in diameter are as thoroughly crystalline in their middle portions as at the granitic contact. At a future time these gneisses will be described. Some notes regarding them may be found in the Seventeenth Annual Report of the United States Geological Survey and in the text of the Big Trees folio.

The granolites[2] of the Sierra Nevada comprise nearly the entire range of granular igneous rocks. Peridotite, pyroxenite, hornblendite, gabbro, diabase, diorite, syenite, monzonite, and granite, with various intermediate types, are all represented. In this paper, however, reference will be made only to the granitic

[1] Published by permission of the Director of the U. S. Geological Survey. A large amount of information has been accumulated about the granular complex of the Sierra Nevada. It is thought better, however, to delay the publication of this material until the field work now under way is completed. There is some confusion in regard to the biotite-granite of the range and the granodiorite and quartz-monzonite. They are, therefore, more fully treated than other types of which only a brief statement is presented here.

[2] The term granolite is here used for all granular igneous rocks; thus diorite, gabbro, syenite, and granite would all be called granolite. It was first suggested by Professor L. V. Pirsson.

rocks or acid granolites, those containing free silica or quartz as an essential constituent, that is to say, in considerable amount.

Seven types of quartz-granolites have thus far been recognized. The relative age of all of them is not definitely ascertained, but so far as known it is expressed in the order in which the different types are enumerated, as follows: biotite-granite, granodiorite, quartz-monzonite, porphyritic quartz-monzonite, Bridal Veil granite, soda-granite and aplite, potash-aplite and pegmatite.

BIOTITE-GRANITE

Biotite-granite forms very large areas in the central portion of the Sierra Nevada. It is particularly abundant in the Big Trees and Yosemite quadrangles,[1] where it has been examined most closely. The coarse biotite-granite is a rock susceptible of easy recognition in the field. Potash-feldspar is an abundant constituent, and by its conspicuous development in relatively large crystals tends to give the rock a porphyritic look. Other minerals less readily seen with the naked eye are quartz and biotite; the former in distinct grains of irregular shape, and the latter so arranged as to give a suggestion of gneissic or banded texture, even in hand specimens. Perfectly fresh specimens are secured with difficulty as the rock weathers to a considerable depth and becomes somewhat friable. Under the microscope the porphyritic texture is generally inconspicuous. The component minerals are soda-lime-feldspar (oligoclase) > quartz > potash-feldspar > biotite > titanite > apatite > zircon. The relative proportions of these minerals are deduced from a calculation as noted later. Chlorite is usually present as a decomposition product of the biotite, and secondary epidote may often be noted. Rutile-like needles were observed in some quartzes.

Biotite-granite usually weathers in yellowish tones, and in forms suggestive of bedding, due to a more or less well-developed gneissic structure. Indeed, at many points the biotite-granite has been greatly compressed and sheared, so that much

[1] As used by the U. S. Geological Survey a quadrangle is the area of country covered by a topographic sheet of the Atlas of the United States.

of it may be called biotite-granite-gneiss. Ilmenite was found in the granite-gneiss, but not in the more massive granite. As the granite-gneiss has, after shearing and compression, undergone recrystallization, the ilmenite may possibly be secondary. At some points the crushing, shearing and recrystallization has been so thorough that the original massive granite has been converted into a moderately fine-grained gneiss.

Analyses have been made of this granite collected at three different points. These analyses show but slight variation in composition. There is also given an average of these three analyses, and from this the molecular composition has been calculated. Analysis 164 is of a biotite-granite which is regarded by Lindgren[4] as representative of the biotite-granite of Pyramid

ANALYSES OF BIOTITE-GRANITE

	1452 S. N.	1485 S. N.	2136 S. N.	Average of Nos. 1452, 1485 and 2136	Molecules of average	164 Pyramid Pk.
SiO_2	70.43[1]	70.75[1]	71.08[2]	70.75	1.1792	77.68[3]
TiO_2	.24	.42	.22	.29	.0036	.14
ZrO_2	....	....	.08	.03	.0002	....
Al_2O_3	15.51	15.13	15.90	15.51	.1521	11.81
Fe_2O_3	.96	.98	.62	.85	.0053	.72
FeO	1.28	1.43	1.31	1.34 }	.0193	.51
MnO	trace	trace	.15	.05 }		trace
NiO	?	none	....	....	....	....
CaO	2.76	3.09	2.60	2.82 }		.72
SrO	.05	.04	.02	.04 }	.0532	....
BaO	.20	.12	.04	.12 }		....
MgO	.37	.73	.54	.55	.0137	.18
K_2O	5.14	3.62	4.08	4.28	.0455	5.00
Na_2O	2.75	3.05	3.54	3.11	.0501	2.96
Li_2O	trace	trace	trace	trace	....	....
H_2O below 110° C.	.08	.10	none	.06	....	.04
H_2O above 110° C.	.40	.51	.30	.40	.0222	.27
P_2O_5	.11	.10	.10	.10	.0007	.10
CO_2	none	none	trace	....	....	....
FeS_2	trace	.06	....	.02	....	....
SO_3	....	....	none	....	....	....
Cl	....	....	.02	.02	.0005	....
Total	100.28	100.13	100.60	100.34	1.5456	100.13

Analyst: [1] Hillebrand. [2] Valentine. [3] Steiger.

[4] Am. Jour. Sci., Vol. III, 1897, p. 307.

Peak quadrangle. It will be noted, however, that the description of the rock by Lindgren indicates that it approximates in texture to a granite-porphyry, and that the chemical composition is nearer that of an aplite than of the biotite-granite to the south of the Pyramid Peak district. I myself have not observed the latter to pass into porphyritic forms with a fine-grained groundmass.

The calculation of the mineral composition is made in the following way. All of the phosphorous pentoxide (P_2O_5) is ascribed to apatite. All the magnesia (MgO) is ascribed to biotite. The molecular ratio of the oxides in the biotite is calculated from an analysis of biotite separated from biotite-granite No. 2136, and as the biotite in all the biotite-granite is optically similar, it is fair to assume that it has, in all three of the granites, averaged, sensibly the same composition. After deducting the titanium oxide (TiO_2) required for the biotite, the remaining titanium oxide is ascribed to titanite. All the zirconium oxide (ZrO_2) is calculated as zircon. After deducting the potash (K_2O) in the biotite, all the remainder is calculated as in potash-feldspar. All the soda (Na_2O) in the rock is supposed to be present in the albite. The chemical analysis[1] of the biotite, however, shows that it contains a little soda (0.38). In calculating the ratio of the oxides in the biotite, the soda was placed

Composition of the biotite-granite, deduced from the average analysis above given		Pyramid Peak, 164. Lindgren
	Per cent.	Per cent.
Quartz	33.06	39.80
Potash-feldspar	20.70	28.17
Soda-feldspar	26.19	25.09
Lime feldspar	12.91	2.47
Biotite	5.64	3.10
Magnetite	.69	.61
Titanite	.55	.35
Apatite	.24	.25
Zircon	.01	......
Water	......	.31
	99.99	100.15

[1] Am. Jour. Sci., 1899.

with the potash. As the biotite forms only about one twentieth of the rock, the error in ignoring the soda in the biotite is small, and would not sensibly alter the result. If, however, the biotite forms a considerable part of the rock, its soda content should be separately calculated and the amount of soda in the biotite deducted from the total soda, the remainder being considered as in albite. After deducting the lime (CaO) for the apatite, titanite, and biotite, the remaining lime is calculated as in anorthite. The oxides of strontium and barium are placed with the lime. After deducting the iron-oxides (Fe_2O_3 and FeO+MnO) for the biotite, all the remaining iron oxides are calculated as in magnetite. After deducting the silica (SiO_2) for the titanite, biotite, and feldspar, all the remaining silica is calculated as quartz.

GRANODIORITE

The granitoid rocks of the Sierra Nevada that were intruded at the close of Jurassic time, may be regarded as portions of one great batholith that may be supposed to underlie the entire range. The quartz-monzonites hereafter described are not regarded as belonging to the granodiorite batholith. All of the areas of this batholith are not connected at the surface, but it is more than probable that these separated areas are merely extruded tongues or gigantic apophyses of the main mass. Viewed from this standpoint, the variation of the chemical and mineral composition of this batholith is extraordinary. The rocks range from acid quartz-diorites containing over 70 per cent. of silica through quartz-mica-diorites, quartz-hornblende-diorites and quartz-pyroxene-diorites to gabbros and even olivine-gabbros. That these different rocks may be regarded as facies of one magma, appears to be indicated by the usual absence of sharp contacts and the existence of transition forms between them. The table of analyses given below probably represents very accurately the chemical variation of the rocks of the batholith. While the authors of the Gold Belt folios have always had in mind, as the typical granodiorite, a rock intermediate between granite and

diorite, in actual use the term in some of my own folios has been applied to all the rocks of which analyses are given in the table, so far as field mapping is concerned, although as a rule gabbro, even when genetically related to granodiorite proper, has been separated. Since the term has been so extensively used for quartz-diorites containing orthoclase, it is thought better to restrict the term to this usage and to call the rocks which are strictly intermediate between granite and diorite, quartz-monzonite.

While there is some doubt as to all of the areas called granodiorite in the folios being actually all portions of one magma, yet there is so great a variation within so many of these areas that the fact that the magma is a greatly variable one is established independently of the consideration of the batholith as a whole.

The evidence that the areas ascribed to this great batholith were intruded at nearly the same time is not altogether satisfactory, but at all places it points in the same direction. That is to say, wherever the granolites composing the batholith come into contact with other rocks, excepting those of post-Jurassic age, it is usually evident that they have metamorphosed those rocks, indicating that they are intrusive in them and are of later age. West of Mariposa the granodiorite has cut off and metamorphosed the Jurassic Mariposa slates into chiastolite- and mica-schists. At Mineral King, in the heart of the Sierra Nevada, to the west of Mt. Whitney, is a lens of Juratrias sediments which has been metamorphosed by granodiorite. The evidence is good that the great bulk of the pyroclastic meta-augite-andesites of the foothills are of Juratrias age. That the granodiorite is intrusive in these rocks at some points, and has metamorphosed them, is evident in the field, as for example, north and east of Mormon Bar in Mariposa county, where the meta-augite-andesite-tuffs have undergone a thorough recrystallization. In Plumas county, southeast of Sierra City, the Juratrias rocks of the Milton formation have likewise been

metamorphosed by granodiorite; also north of Genesee Valley[1] there is a quartz-gabbro which is a basic facies of the great batholith, and the adjoining Triassic slates have been metamorphosed into hornfels. There is also evidence that the rocks of this batholith are later in age than the serpentines and associated magnesian rocks. This is particularly evident in the Bidwell Bar quadrangle, where the rocks of the magnesian series are cut by dikes of granodiorite, and in general throughout this quadrangle the rocks surrounding the granodiorite areas, whether of sedimentary or of igneous origin, show contact metamorphism. However, in the Bidwell Bar quadrangle the age of the sedimentary rocks, so far as known, is Carboniferous, and it can therefore only be said that in this region the granodiorite is post-Carboniferous.

In a paper[2] published in 1893, Lindgren describes typical granodiorite as follows: "The rock consists in typical development of feldspar, quartz, biotite, and hornblende with medium-grained hypidiomorphic structure. The soda-lime-feldspars are usually considerably and to a variable extent in excess of the alkali-feldspars. The silica varies between 60 and 73 per cent.; the amount of lime is variable, but it rarely exceeds, while it usually falls somewhat short of, the sum of the alkalies. While in some varieties which cannot be distinguished from the others in the field, there is more potash than soda, a frequently occurring relation is 2 per cent. Ka_2O to 4 per cent. Na_2O. It will be seen that the rock very closely approaches some quartz-mica-diorites and often might be indicated by that name."

In his later paper on the gold quartz veins of Nevada City and Grass Valley, published in the Seventeenth Annual Report of the U. S. Geological Survey, Lindgren gives the limits of chemical variation and average composition of granodiorite as follows.

[1] DILLER, Bull. 150 U. S. Geol. Surv., p. 338.

[2] The Auriferous Veins of Meadow Lake, California. Am. Jour. Sci., Vol. XLVI, 1893, pp. 202, 203.

In his investigation of Pyramid Peak quadrangle, Lindgren found large areas of granitic rocks containing amphibole and biotite and resembling granodiorite in a general way. Some of these rocks are somewhat basic and probably correspond to the granodiorite of the Gold Belt region in chemical composition; but other areas contain more alkali and less lime than the typical granodiorite of this paper. Lindgren, however, concluded that this alkali-rich rock should be called the typical granodiorite, inasmuch as it occurs in very large areas, and also since it occupies a place almost exactly intermediate between quartz-diorite and granite. Since that time much field work has been done in the south central Sierra Nevada where the granular complex is finely exposed, most of the soil and loose rock having been removed by the glaciers that formerly covered the region. The opportunities, therefore, of studying the relations of the granites in this section are unexcelled. The different granitic rocks resemble one another so much in general aspect that the contacts between different kinds are sometimes discovered only after careful search. As a rule a person will pass from one kind of granite to another without having observed any change in the rock until the difference is called to his attention by some striking feature. It is not to be wondered

LIMITS OF VARIATION AND AVERAGE COMPOSITION OF GRANODIORITE

	Limits of variation	Average composition
	Per cent.	Per cent.
SiO_2	59 to 68½	65
Al_2O_3	14 to 17	16
Fe_2O_3	1½ to 2¼	1.50
FeO	1½ to 4½	3
CaO	3 to 6½	5
MgO	1 to 2½ [1]	2
K_2O	1 [2] to 3½	2.25
Na_2O	2½ to 4½	3.50
Remainder	....	1.75
		100

[1] Three and one half in one analysis.

[2] Certain masses in the foothills go below 1 per cent.

at, therefore, that the relations of the different granites is not yet clearly understood. The exposures at a number of points clearly show that the granodiorite proper is intrusive in, and therefore younger than, the biotite-granite. Other exposures near Yosemite Valley show a sharp contact between the rock here called quartz-monzonite and granodiorite proper. While the evidence of these two rocks being distinct is not altogether satisfactory at present, it is probable that the quartz-monzonite is later in age than the granodiorite. In order to show the chemical relations of granodiorite to related rocks, some partial analyses are here given:

		Granodiorite series		Quartz-monzonite		103 Pyramid Peak
	Tonalite	Quartz-diorite	Granodiorite	Banatite	Adamellite	
Silica	66.91	57.74	65.48	64.39	68.39	67.45
Alumina	15.20	17.36	16.05	15.90	13.47	15.51
Lime	3.73	6.81	4.88	4.15	3.24	3.60
Magnesia	2.35	3.62	2.13	1.93	1.02	1.10
Potash	.86	2.01	2.43	3.57	3.28	3.66
Soda	3.33	3.07	3.49	3.48	3.85	3.47

The rock described by vom Rath and called tonalite, has sometimes been regarded as a synonym for granodiorite. That such is not the case, however, will appear from the analysis given above. If this analysis is reliable it is clear that tonalite is a typical quartz-diorite unusually rich in silica. The analysis of the tonalite is the mean of two analyses by Kenngott.[1] The specimen analyzed came from Avio See and vom Rath,[2] who originated the name, analyzed the plagioclase of the tonalite of Adamello, and found the feldspar to be basic andesine

The quartz-diorite analysis may be regarded as a fair average of the smaller granodiorite areas noted in the Gold Belt folios and of the marginal portions of larger areas. This analysis is the mean of five basic quartz-diorite analyses given in the large table of granodiorite analyses.

[1] Zeit. Geol. Ges., Vol. XVII, 1865, p. 572.

[2] Zeit. Geol. Ges., Vol. XVI, 1864, p. 249.

ANALYSES OF ROCKS FROM THE POST-JURASSIC GRANODIORITE BATHOLITH OF THE SIERRA NEVADA

	Olivine gabbro	Basic quartz-diorites					Granodiorites proper					Acid quartz-diorites	
	No. 941 S. N.[1]	No. 1495 S. N.[2]	No. 225 S. N.[2]	No. 936 S. N.[2]	No. 851 S. N.[3]	No. 691 S. N.[1]	No. 369 S. N.[2]	No. 17 S. N.[2]	Grass Valley[2]	Nevada City[2]	No. 71 S. N.[2]	No. 303 S. N.[2]	No. 22 S. N.[2]
SiO_2	43.41	55.86	57.26	57.80	58.09	59.68	62.62	63.43	63.85	66.65	67.33	68.65	70.36
TiO_2	.39	1.20	.53	.70	.95	.65	.55	.73	.58	.38	.36	.28	.20
Al_2O_3	23.15	19.30	16.51	16.43	17.46	17.09	17.51	14.20	15.84	16.15	15.93	16.34	15.47
Cr_2O_3	none	....	none	none	....	none	....	....	....	....	....	....	....
Fe_2O_3	3.72	.91	3.27	1.62	1.12	2.85	.49	1.54	1.91	1.52	1.90	.93	.98
FeO	4.39	4.78	5.19	6.51	5.08	2.75	4.06	4.56	2.75	2.36	1.59	1.48	1.17
MnO	.08	.16	.18	.18	none	trace	.05	.03	.07	.10	.09	.08	trace
NiO	none	trace	trace?	.03	....	none	....	....	....	....	....	....	....
CaO	14.27	7.31	6.69	7.21	6.24	6.62	5.49	5.51	4.76	4.53	4.09	3.07	3.18
SrO	none	.04	.06	trace?	.04	trace	trace	trace	trace	trace	trace	.07	trace
BaO	none	.13	.10	.09	.07	.04	trace	.06	.06	.07	.08	.09	.06
MgO	7.65	2.94	3.41	4.14	4.06	3.54	2.84	2.35	2.07	1.74	1.63	1.29	.87
K_2O	.22	1.52	2.93	2.29	2.02	1.31	1.76	2.19	3.08	2.65	2.46	1.85	1.71
Na_2O	.82	3.52	2.65	2.35	2.94	3.87	3.49	3.49	3.29	3.40	3.76	4.85	4.91
Li_2O	trace	trace	trace	trace	none	trace	trace	none	trace	trace	trace	trace	trace
H_2O below 110° C.	.18	.19	.20	.11	.29	.15	.22	.15	.28	.18	.19	.24	.06
H_2O above 110° C.	1.53	1.23	.95	.38	1.45	1.00	.92	1.50	1.65	.72	.66	.62	1.00
P_2O_5	.02	.38	.30	.19	.17	.25	.12	.11	.13	.10	.11	.15	.11
CO_2	.10	none	none	none	.21	.20	....	....	....	....	....	....	....
FeS_2	.14	.39	none	none	c. .11	none	....	....	.04	.02	....	....	....
SO_3	....	....	....	....	.05	trace	....	....	....	....	....	....	....
Cl	trace	....	....	....	.02	.03	....	....	....	....	....	....	....
F	....	....	....	....	trace	none	....	....	....	....	....	....	....
Total	100.09	99.86	100.23	100.03	100.37	100.03	100.12	99.85	100.36	100.57	100.18	99.99	100.08

Analyst: [1] Stokes, [2] Hillebrand, [3] Steiger.

The granodiorite analysis may be regarded as typical of that rock and as representing the average rock of many areas. The analysis is the mean of the five analyses given in the large table. A comparison with the banatite analysis indicates a close relationship, but a granodiorite very seldom attains so high an alkali content as that of a banatite. The banatite analysis is a mean of five analyses by Brögger.[1] The analysis of the adamellite is a mean of six analyses by Brögger.[2] The quartz-monzonite analysis 103 Pyramid Peak is Lindgren's typical granodiorite of his latest paper.[3] It is clear that this rock would be placed with the monzonites by Brögger.

Granodiorite when typical is composed of plagioclase (oligoclase-andesine, but usually andesine) > quartz > orthoclase. Biotite and green aluminous amphibole are abundant constituents, but are variable in their relative amounts, and at times only one of these ferro-magnesian elements is present. Magnetite, titanite, and apatite are nearly always present as accessories. The rock is usually evenly granular in texture and of a light gray color.

QUARTZ-MONZONITE

As has already been stated under granodiorite, there are very large areas of a rock containing amphibole and biotite which resembles granodiorite and perhaps may be related to it genetically. From the analyses given below it will be seen, however, that the rock is richer in alkali and poorer in lime than the most acid of the granodiorites of the Gold Belt. This rock forms part of the east wall of Yosemite Valley and Half Dome, North Dome, Starr King, and other points. In general it is quite massive and thus lends itself to a method of weathering called exfoliation, which ordinarily results in the production of dome-like forms. It is composed of oligoclase > quartz > orthoclase > biotite > amphibole. There are present as accessories titanite, apatite, iron ore, and zircon. It thus strongly resembles grano-

[1] Die Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo, p. 62.

[2] *Ibid.*, p. 62.

[3] Am. Jour. Sci., 1897.

ANALYSES OF GRANITIC ROCKS

	Quartz-monzonite			Porphyritic quartz-monzonite	Soda-granite and aplite			Quartz-diorite aplite	Quartz-diorite
	No. 2179 S. N.	No. 1751 S. N.	No. 103 Pyramid Peak	No. 39 S. N.	No. 399 S. N.	No. 413 S. N	No. 725 S. N.	No. 1490 S. N.	No. 1495 S. N.
SiO_2	66.83	66.91	67.45	66.28	73.18	74.21	76.00	69.66	55.86
TiO_2	.54	...	.58	.54	.25	.30	.04	.21	1.20
ZrO_2	.04	...	...	...	...	...	...	...	...
Al_2O_3	15.24	...	15.51	16.03	13.66	14.47	14.88	17.57	19.30
V_2O_3	...	.01 [1]	...	...	...	...	...	...	...
Fe_2O_3	2.73	...	1.76	1.80	.21	.35	.65	.21	.91
FeO	1.66	...	2.21	1.88	2.24	.50	.10	1.04	4.78
MnO	.10	...	...	.05	.07	none	trace	trace	.16
NiO	...	...	...	...	...	...	none	none	trace
CaO	3.59	3.51	3.60	3.75	2.10	1.71	.19	4.54	7.31
SrO	.03	...	...	trace	trace	trace	none	.05	.04
BaO	.11	...	...	.08	.10	none	trace	.03	.13
MgO	1.63	...	1.10	1.12	.93	.28	.06	.58	2.94
K_2O	4.46	3.13	3.66	3.49	2.72	.10	2.77	.71	1.52
Na_2O	3.10	3.59	3.47	4.10	3.70	7.62	3.52	4.91	3.52
Li_2O	trace	trace	...	trace	trace	trace	none	none	trace
H_2O below 110° C.	none	...	.14	.11	.10	.15	.20	.05	.19
H_2O above 110° C.	.56	...	.63	.39	.57	.23	1.42	.50	1.23
P_2O_5	.18	...	.12	.30	.09	.07	.11	.03	.38
CO_2	trace	...	...	...	.17	...	none	none	none
FeS_2	...	...	...	...	...	...	...	trace	.39
SO_3	none	...	...	...	...	...	...	...	...
Cl	.02	...	...	...	...	...	...	...	...
F	...	...	...	...	...	...	...	...	...
Total	100.82	...	100.25	99.92	100.09	99.99	99.94	100.09	99.86
Analyst	Valentine	Stokes	Steiger	Hillebrand	Hillebrand	Hillebrand	Stokes	Hillebrand S = trace	Hillebrand S = 0.21

[1] The V_2O_3 det. by Hillebrand.

diorite in mineral composition. One of the chief differences is the more acid character of the plagioclase which is, so far as known, always oligoclase. It also contains zircon, which is not usually found, and certainly is not abundant, in granodiorite. It is probably, moreover, of later age. The quartz-monzonite of the Sierra Nevada would be called a hornblende-biotite-granite by Rosenbusch. The three analyses given in the table below indicate that the chemical composition of this rock is remarkably uniform. The quartz-monzonite of the east wall of Yosemite Valley appears to be in sharp contact with the granodiorite mass that lies immediately west. At any rate the transition from the even-grained monzonite with scattered amphiboles to the more basic granodiorite, occurs within a very few feet at a number of points. More investigation, however, is needed.

The adoption of the term quartz-monzonite instead of granodiorite will perhaps be objected to by some petrographers on the ground that granodiorite is the older term. As has been shown, however, the latter rock does not occupy a strictly intermediate position between granite and quartz-diorite unless we extend the range of its chemical variation so as to include the quartz-monzonite of the higher parts of the Sierra. If we should confine the term quartz-monzonite, or granite-diorite, to quartz-feldspar rocks in which the potash and soda-lime feldspar are present in about equal amount, as Brögger has done, we would then have to exclude from this type nearly all of the rocks called granodiorite (quartz-orthoclase-diorite) in the Gold Belt folios. It would, therefore, seem better to let the term granodiorite stand for the rocks for which it has been used, and use one of the perfectly definite terms quartz-monzonite or granite-diorite for the rocks intermediate between granite and quartz-diorite. The term monzonite has already been adopted by the United States Geological Survey for folio use, and it seems, therefore, desirable for the members of the survey likewise to use the term quartz-monzonite for monzonites containing abundant quartz, in the same way that we use quartz-diorite for diorites containing abundant quartz.

THE PORPHYRITIC QUARTZ-MONZONITE[1]

Forming large areas along the higher parts of the range is a coarse granitic rock containing numerous porphyritic orthoclases which are often more than two inches in length. This rock is in sharp contact with the quartz-monzonite, above described, to the northwest of Lake Tenaya in the Yosemite Park, and doubtless at other points. While not differing much in chemical composition (see No. 39, table of analyses) from the latter rock, its marked porphyritic character and the usual absence of amphibole readily distinguish it. Along the contact, however, the porphyritic quartz-monzonite sometimes contains abundant amphibole. The orthoclase phenocrysts are evidently formed at a late period in the consolidation of the rock, for these contain as inclusions most of the minerals of the groundmass, including plagioclase, biotite, quartz, titanite, and iron oxide. The inclusions have no definite arrangement in the phenocrysts.

BRIDAL VEIL GRANITE

In the drainage of Bridal Veil Creek, on Horse Ridge, and at many other points in the Yosemite Park, there are considerable masses of a white, rather fine-grained granite which has been designated Bridal Veil granite. It often shows an orbicular structure, there being a central white nucleus composed of quartz and feldspar, surrounded by a layer rich in biotite. This granite is intrusive in the biotite granite and often contains near the contact chunks of the latter. It also incloses fragments of dioritic rocks, which are likewise found as nodules and small areas in

ANALYSES OF BRIDAL VEIL GRANITE

	No. 2558 S. N.	No. 2051 S. N.
SiO_2	71.45	69.81
CaO	2.40	2.31
K_2O	3.25	5.25
N_2O	3.53	2.79

[1] Fourteenth Ann. Rep. U. S. Geol. Surv., pp. 478–480.

some of the other granites. No complete analysis has been made of this granite, but there are given above two partial analyses which indicate some variation in chemical composition if they are in reality both from the same magma.

No. 2558 is from north Cathedral Rock in Yosemite Valley, and No. 2051 is from a dike in the bed of the Middle Tuolumne River, about 4.5 kilometers northeast of Bald Mountain. Both analyses were made by Dr. H. N. Stokes.

SODA-GRANITE AND APLITE

Granitic rocks rich in soda are not abundant in the Sierra Nevada. The largest mass known lies east of Cathay Valley in Mariposa county. This area is clearly later than the diabase that is found to the west. Along the contact in and southeast of Cathay Valley a contact-breccia has been formed which is a mile or more in width. This is composed of fragments of the diabase cemented by the soda-granite. On the northeast the aplite area is in contact with the slates of the Mariposa formation. These slates are flinty near the contact on Agua Fria Creek, where also they are of a peculiar light gray color. Microscopic examination does not show any very marked metamorphism. Near the contact, however, the granitic rock is richer in lime (analysis 399, S. N.), which it may have absorbed (?) from the slates. The rock may also be regarded as a basic contact facies due to differentiation. In either case the above facts suggest that the granite is later in age than the Jurassic Mariposa slates. No. 399 was collected on Agua Fria Creek near the Mariposa slates, 5.2 km southwest of Mariposa. It is composed of micropegmatite, quartz, oligoclase, biotite, ilmenite, and epidote. Orthoclase is probably present although not determined in the thin section. Some of the epidote is wedged in between the other constituents all of which are fresh. This epidote is probably primary.

No. 413 is from the interior of the area above described, 6.5 km west of Mariposa. This was estimated to be a fair average sample of the rock. It is composed largely of albite and micro-

pegmatite, with less quartz, titanite, apatite, epidote, pyroxene, and uralite. A rough calculation shows that this rock is composed of about 64 per cent. of albite, 25 per cent. quartz, the remaining 11 per cent. including pyroxene, titanite, apatite, epidote and uralite. It is thus a true soda-granite.

South of the locality at which 399 was collected, on Agua Fria Creek, the soda-aplite is in sharp contact with granodiorite, but there was no satisfactory evidence found of the relative age of the two rocks. At the head of Owen's Creek, to the west of Cathay Valley, there is better evidence of the age of the soda-granite. The clay slates, which are pretty certainly of Juratrias age, are here clearly metamorphosed by the granitic rock.

In Butte and Plumas counties white dikes are abundant in metamorphic magnesian rocks, which are altered peridotites and pyroxenites. These dikes are mostly composed of quartz and albite, but in some muscovite is present. Analysis 725 is of a specimen collected from a dike in serpentine on Grizzly Hill in Plumas county. It is composed chiefly of spherulites of quartz and albite, micropegmatite, and abundant muscovite, the latter mineral chiefly in little rosettes. It has elsewhere[1] been suggested that these dikes of soda-granite and aplite are in some way genetically related to the peridotites and pyroxenites or other basic rocks with which they are usually associated.

The aplite dikes in the gneisses and associated granites.—In the bed of the North Mokelumne and other points there are irregular white dikes in the gneisses and associated granitic rocks. Some of these dikes are of evenly granular texture throughout, and may be called aplites; others are banded. A chemical analysis has been made of only one of these dikes, and this analysis taken in connection with the microscopical examination indicates that the rock is rich in soda, and hence the aplites in the gneisses are placed with the soda-aplites. It is by no means certain, however, that they are all alike in composition. Some of these dikes contain garnets. The aplites in the gneisses and

[1] Bidwell Bar folio of the Atlas of the U. S. Geol. Surv.

older granite are supposed to be older than the potash-aplites of the granodiorite series.

PARTIAL ANALYSIS OF SODA-APLITE (NO. 1730). ANALYST, STOKES

SiO_2	76.17
CaO	1.64
K_2O	2.48
Na_2O	4.54

No. 1730 is a dike in gneiss from the north bank of the Mokelumne[1] a little below the mouth of Blue Creek in the Big Trees quadrangle. This rock is made up chiefly of quartz and feldspar. In addition there is a little biotite present. For the purpose, however, of a rough calculation this biotite can be ignored and all the lime ascribed to anorthite, all the soda to albite, and all the potash to orthoclase or microcline. Nearly all the alumina of the rock is contained in the feldspar molecules. The amount of alumina may therefore be calculated, and equals .1289 molecules, or by weight 13.15 per cent. The free silica can be estimated by deducting from the total silica the amount in the feldspar.

Total silica	1.2695
Silica in feldspar	.6562
Free silica	.6133

The molecular composition of soda-aplite No. 1730 is then approximately as follows.

	Molecules	Percentage
Potash-feldspar	.2112	13.83
Soda-feldspar	.5856	38.34
Lime-feldspar	.1172	7.67
Quartz	.6133	40.16
	1.5273	100.

The albite and anorthite molecules together form plagioclase, the ratio being $Ab_5\ An_1$; hence the plagioclase is acid oligoclase. The potash-feldspar is chiefly or entirely microcline. The relative abundance of the constituents of soda-aplite No.

[1] See Seventeenth Ann. Rep. U. S. Geol. Surv., Part I, p. 700–705, for other notes about these gneisses.

1730 may be stated as follows: oligoclase > quartz > microcline > biotite.

Quartz-diorite-aplite.—In the bed of Bear River, Big Trees quadrangle, there are small white dikes from two to ten centimeters or more in width, occupying straight fissures in gneiss and quartz-diorite. The dikes have an aplitic texture and are much more acid than the quartz-diorite. It may be assumed that they bear a genetic relation to the diorite, similar to that existing between the potash-aplites hereafter described and the granodiorite and quartz-monzonite. In the table of analyses with the soda-granites there is given the chemical composition of one of these dikes (No. 1490) as well as that of the quartz-diorite (No. 1495) in which they occur. No. 1490[1] is practically an aplite, the feldspar, however, being probably chiefly andesine. The enclosing quartz-diorite is quite basic and we thus have a suggestion that the composition of aplitic dikes is determined by the composition of the granitic rock in which they occur. Rosenbusch[2] refers to tonalite-aplite and diorite-aplite and the dikes above described might be designated tonalite or quartz-diorite-aplite, following Rosenbusch. It should be noted, however, that by some authors the term aplite is restricted to granites composed chiefly of quartz and alkali-feldspar. If, however, dikes occur in various magmas which, while varying in composition, show a direct genetic relation to these magmas, some group term for such dikes is desirable.

The potash-aplites and pegmatites of the granodiorite series.—At a great number of points in the Sierra Nevada, there are dikes of a white rock from a few inches to a few feet in width. In the granodiorite and quartz-diorite these dikes are usually medium-grained with only occasional dark constituents. They grade over into pegmatite. The pegmatitic facies will, however, be treated in a later paragraph. This aplitic granite is composed of quartz > potash-feldspar > soda—lime-feldspar (oligoclase) > biotite > magnetite > apatite.

[1] Seventeenth Ann. Rep. U. S. Geol. Surv., Part I, p. 704.

[2] Mikroskopische Physiographie der massigen Gesteine, 1896, p. 464.

The chemical analysis given below shows more titanium oxide than is required for the biotite. Inasmuch as all the iron oxide is magnetic and therefore probably magnetite, it is likely that there is no ilmenite present. The remaining titanium oxide is therefore supposed to be present in titanite, which is the most common titanium mineral in the Sierra Nevada granites. This mineral was not, however, found in the thin sections. The relative proportions of these different minerals are taken from the calculation, as given below.

It is well known that as a general rule, the less siliceous elements crystallize out first and the more siliceous last in rock magmas. In most quartz-diorite and granitic magmas the alkali-feldspar and quartz are usually the last elements to crystallize, and they are, also, the most acid of the components of the rock. A possible explanation of the occurrence of aplite dikes in quartz-diorite and granitic magmas would appear to result from this law of crystallization. We have but to suppose that after the crystallization of the less siliceous constituents there is a residual mass of orthoclase and quartz in solution which is afterwards forced into fractures which form in the already consolidated granite, perhaps as the result of cooling. The laws of thermo-chemistry would appear to be applicable to such a scheme. Heat would be generated by the crystallization of the minerals of the granite and this heat would perhaps aid in establishing convection currents to transport the residual, more siliceous, constituents away from the already consolidated material. Moreover, as suggested by Dr. Hillebrand, the more siliceous material would be crowded away by the minerals which crystallize first, in the same way as the salt of sea water is crowded out by the crystallization of the water, so that the residual sea water, after a portion has crystallized or frozen, contains more salt, proportionately, than the sea water before crystallization began.

The following calculation of the relative molecular proportions of the various minerals found in the granodiorite-aplites is based on the average of two complete chemical analyses by Dr. Hillebrand, given in the table below. The calculation is

made in the same way as for the biotite-granite. The biotite in the aplites being similar to that of the biotite-granite, it is supposed to have the same chemical composition. The result of the computation is as follows.

COMPOSITION OF THE GRANODIORITE-APLITE

	Molecules	Percentage
Quartz	.6058	39.45
Potash-feldspar	.4520	29.43
Soda-feldspar	.3536	23.03
Lime-feldspar	.1008	6.56
Biotite	.0138	.90
Magnetite	.0061	.40
Titanite	.0027	.18
Apatite	.0008	.05
	1.5356	100.00
Total molecules	1.5523	
Not accounted for	.0167	

ANALYSES OF POTASH APLITES

	159 Nevada city	No. 227 S. N.	No. 161 S. N.	Average of 227 and 161	Molecular proportions of the average
SiO_2	77.05[1]	75.97[2]	76.03[2]	76.00	1.2667
TiO_2		.09	.07	.08	.0010
Al_2O_3		13.07	13.39	13.23	.1297
Cr_2O_3		none			
Fe_2O_3		.61	.48	.54	.0034
FeO		.39	.31	.35	.0049
MnO		trace	trace	trace	
NiO		none			
CaO	.73	1.49	1.28	1.38	
SrO		.03	trace	.02 } 1.49	.0266
BaO		.14	.04	.09	
MgO		.14	.05	.09	.0022
K_2O	5.06	5.62	5.18	5.40	.0574
Na_2O	3.43	2.51	2.98	2.74	.0442
Li_2O		trace	none		
H_2O below 110° C.		.14	.15	.14	
H_2O above 110° C.		.24	.34	.29	.0161
P_2O_5		trace	.03	.02	.00014
CO_2		none			
Total		100.44	100.33	100.37	1.5523

Analyst: [1] Stokes. [2] Hillebrand.

159, N. C. is taken from Lindgren's paper in the Seventeenth Ann. Rep., U. S. Geol. Surv., Part 2, p. 45.

227, S. N. Dike in quartz-mica-diorite (No. 225, S. N.) about 3.2 km. east of Milton in the Downieville quadrangle The dike is about 60 cm. wide.

171, S. N. Dike in the quartz-mica-diorite about 11 km. east of the Sierra Buttes, Downieville quadrangle. The dike is quite wide and is intersected by joints, the most prominent set being nearly vertical.

Pegmatites.—The pegmatites which are associated with granodiorite and quartz-monzonite are very often banded, the border

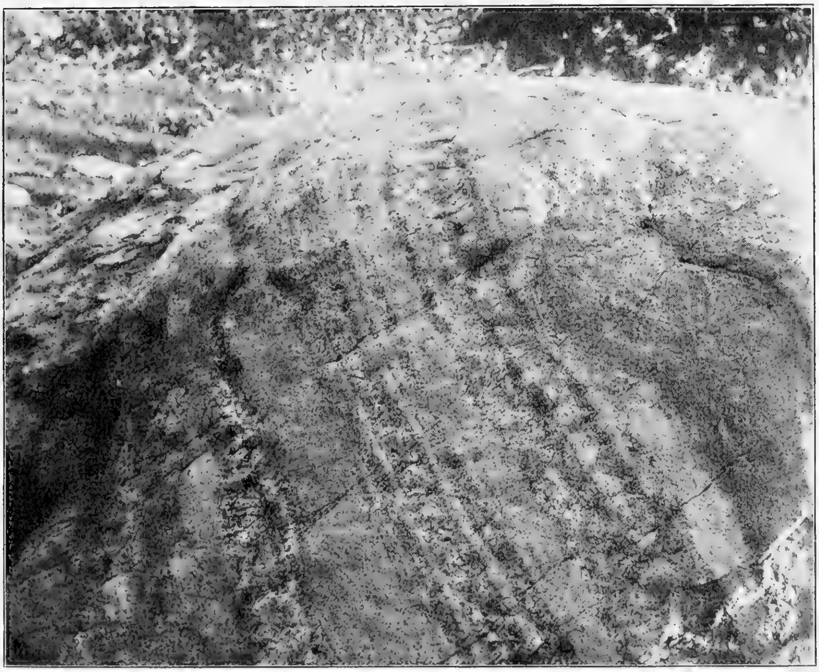


FIG. 1.—Boulder of aplite-pegmatite on ridge south of Highland Creek in the Big Trees quadrangle.

of the dike being aplite and the middle layer pegmatite, thus forming a suggestion of the "comb" structure shown in some quartz veins. In certain cases the banding is repeated, there being several layers of aplite with pegmatite between. This is

shown in Fig. 1. In the more acid dikes or veins (?) the middle band is quartz with aplite borders.

It is not yet ascertained whether the aplites and pegmatites occurring in the different granites of the Sierra Nevada show characteristic differences that are constant. The oligoclase-aplite (No. 1730), previously described as coming from the North Mokelumne River, was presumed in the field to be typical of the aplites of the gneisses and biotite-granite; but it remains to be shown if there is not considerable diversity in these dikes. There are, for example, in the Yosemite quadrangle, in biotite-granite, sporadic bunches of white platy quartz interspersed with chunks of flesh-colored orthoclase or microcline. This forms practically a coarse pegmatite. The quartz in these bunches greatly exceeds in amount the potash-feldspar so far as my observation goes. One bunch of white quartz by the trail to the "Fissures" south of Yosemite Valley is 18 meters long and 14 wide, with chunks of potash-feldspar; but nine tenths of the mass is quartz. Some of the pegmatite in biotite-granite is distinctly banded,[1] the same as in granodiorite.

H. W. TURNER.

[1] Seventeenth Ann. Rep., U. S. Geol. Surv., Part I, p. 700, Plate XXXIV.

Studies for Students.

THE DEVELOPMENT AND GEOLOGICAL RELATIONS OF THE VERTEBRATES.

V. MAMMALIA.—(*Continued.*)

HIPPOIDEA, *Equidae.*—The phylogeny of the horses has been made out by a study of the gradual changes which succeeded one another in the development of the modern form of the teeth and the foot structure. A nearly perfect series of these changes is known, and besides the direct line of the development of the horse, there have been demonstrated several side lines, all of which have become extinct. The earliest form that can be definitely stated as belonging to the line of the horses is *Hyracotherium*, from the Lower Eocene of the continent of Europe, England, and the United States. It is to be noticed that it does not occur in the lowest Eocene; thus it is not found in the Puerco of the United States, with the *Condylarthra*, but is found in the Wasatch, Green River, and the Bridger. There are four digits on the front foot and five on the hind foot, the three middle digits being functional on both feet; the fibula and the ulna of the fore part of the front and hind limbs are fully formed, and show nothing of the reduction that they subsequently undergo. The upper molars are different from the premolars, and are furnished with six tubercles, an outer pair and an inner pair, and between these another pair that is smaller.

Pachynolophus is from practically the same horizons as the *Hyracotherium* in America and on the continent. It represents a short step in advance; the ulna and the fibula are smaller and barely reach the end of the radius and the tibia. The two inner tubercles of the teeth are elongated laterally and almost join the two middle ones. This form includes, according to Osborn,

a large number of genera from both the old and the new worlds that have been described from separate teeth and fragmental bones.

Epihippus from the Uinta and Bridger and *Propaleotherium* from the Middle Eocene of the Paris Basin, are very close to the *Pachynolophus*, but the inner tubercles of the upper molars are more perfectly joined to the middle tubercles, so that there is a short ridge on both the anterior and the posterior portion of the inner side of the tooth.

Mesohippus from the Oligocene of the United States, White River, and *Paleotherium* from the Upper Eocene and the Oligocene of France, are the best representatives of the next step. In these forms there are only three digits on the front and hind feet, the fourth digit on the front foot being reduced to a mere splint bone with no trace of terminal phalanges. The ulna and the fibula are greatly reduced and scarcely reach to the distal ends of the radius and the tibia. The connections between the two inner sets of tubercles of the upper molars have developed into strong cross ridges which extend well out to the outer border of the tooth and nearly touch the anterior edges of the corresponding tubercles.

Anchitherium is now regarded as little off the main line of descent of the true horses, but as it represents very closely the succeeding stage that is properly indicated by a poorly known form, *Desmatippus*, from the Deep River beds of Oregon, it may properly be described here.

Anchitherium is one of the most common forms of the Upper and the Middle Miocene of the continent of Europe and the United States. The fourth digit of the front foot is reduced to a mere ossicle of bone at the upper end of the third digit. The distal ends of the ulna and the fibula have entirely disappeared, so that the bone ends free in the middle part. The teeth show the cross ridges of the upper molars extending out to the outer tubercles and joined with them. One of the most important changes of the series that developed the horse appears in this form; the enamel on the upper portion of the cross ridges dis-

appears and permits the cement below to appear at the surface. Now, as the cement is softer than the enamel, the wear of the tooth will serve to keep this inner part lower than the enamel walls, and there will always be sharp edges to serve for grinding up the grass and other herbage that forms the food of the animal.

Protohippus and *Merychippus* from the Pliocene of North America are the next forms in the series. The two lateral digits of the feet, two and four, are shortened and do not reach the ground, though they still retain all the phalanges. The ulna and the fibula are reduced to short splints, confined to the proximal ends of the radius and the tibia. The molars are very horse-like in the fact that all the tubercles have lost the enamel from the upper surfaces, and there are great "lakes" of cement, bordered by sharp enamel edges, for grinding the food.

Hipparion is a form somewhat off the line of the horses, but differs little from the *Protohippus*. It was very common in the Miocene time both in North America and in Europe. It extended up into the Pliocene in Africa and Asia.

Pliohippus and *Equus* are from the Pliocene deposits of most of the world, and from there upward the deposits of the Pleistocene and the recent times show their presence, except that *Pliohippus* is absent in the Recent. It is of interest to note that though the continent of North America was undoubtedly the original home of the horses and the theater of their greatest development, that at the end of the Pleistocene time they seem to have disappeared from the continent, and were only reintroduced by man when the Spaniards brought them over to aid in the conquest of Mexico.

The last two genera are distinguished by the reduction of the two lateral digits to two splint bones on the proximal end of the cannon bone and the nearly complete loss of the ulna and the fibula; the latter remains only as the olecranon process.

The phylogeny of the horse series has thus been arranged by Mr. Farr, a late writer on the subject.

Pliocene to Recent *Equus*

Hippidium

Loup Fork	*Protohippus*
	Hipparion
Deep River	*Desmatippus*
	Anchitherium
John Day	*Mesohippus*
White River	*Mesohippus*
Uinta	*Epihippus*
Bridger	*Pachynolophus*
Wasatch	*Hyracotherium*
	Paleotherium
Puerco	*Condylarthra*

The earliest of the horses must have presented a very different appearance from the horse as we know it. They were scarcely larger than a small dog and had rather the appearance of one than of a horse. The Miocene members of the group were about the size of a small pony, with very delicate limbs. According to Osborn, they were, in all probability, marked very much like the zebra. The *Anchitherium*, *Hipparion*, and the earliest true horses were somewhat smaller than the recent horse, but could not have been very different in their external appearance.

Paleotheridae.—This is the more primitive of the two families. It is known only from the Upper Eocene deposits of Europe, but there are several closely related later forms both in Europe and America. *Anchitherium* and *Pachynolophus*, described among the *Equidae*, are by some authors regarded as more closely related to the *Paleotheridae*.

Paleotherium, from the Upper Eocene of the Paris Basin, is the typical genus. The dentition is complete, but the premolars have assumed the appearance of molars. There were three toes on each foot, all reaching to the ground. The surfaces of the teeth are covered with enamel and have not begun to show the "lakes" of cement that characterize the teeth of the true horses. The largest, from *P. magnum*, was about the size of a rhinoceros.

The Tapiroidea has the two families *Tapiridae* and *Lophiodontidae*. In common with the other Perissodactyls, they seem to

have their origin in the earliest Eocene from some animal closely related to the *Hyracotherium*. In general they were stout-bodied animals of medium size, with three digits on the posterior foot and four on the anterior; the upper teeth developed in the more recent forms a pair of transverse parallel ridges that are characteristic of the group.

Early in the history of the group it divided into the two families, which took different lines of development, the *Tapiridae* working out the condition of the modern Tapirs and the *Lophiodontidae*, which assumed somewhat the characters of the rhinoceroses and became extinct in the late Eocene or Middle Miocene.

Tapiridae. — The line of development of the modern Tapirs is expressed as follows by Wortman and Earle: *Systemodon* of the Wind River; *Isectolophus latidens*, Bridger; *I. annectens*, Uinta; *Protapirus*, White River, and possibly *Tapiravus*, of the Loup Fork. Speaking of this family, Smith Woodward says: "The family thus characterized dates back to the Lower Miocene (White River Formation) in the United States of America, and apparently to the same remote period in Europe. In the Tapirs of this early date the premolars are slightly simpler than those of the surviving genus *Tapirus;* while *Tapiravus*, ranging through the Miocene and Pliocene of North America, is still somewhat primitive in the same feature. The typical *Tapirus* itself, however, is represented in Europe by several fine specimens from the Lower Pliocene of Eppelsheim, Hesse-Darmstadt (*T. priscus*), and from the corresponding formations in Hungary and southeastern Austria; also by remains from the Pliocene of France and Italy, and by detached teeth from the Red Crag of Suffolk. It is also to be noted that other teeth, indistinguishable from those of *Tapirus*, occur in an Upper Tertiary (probably Pliocene) formation in China. It is thus evident that during Miocene and Pliocene times these animals ranged over most of the warm and temperate lands of the northern hemisphere. Hence is explained the remarkable distribution of the existing Tapirs, which are confined to two widely separated areas, namely,

(1) certain portions of the Indo-Malayan region, and (2) the tropical parts of America."

Lophiodontidae.—In defining this family Osborn and Wortman indicate its position by referring to it as "A family of Lophodont Perissodactyls intermediate in position between the *Tapiridae* and the *Hyracodontidae.* The genera referred to this family are *Lophiodon* from the Middle Eocene of Europe, *Heptodon* of the Wasatch, *Helaletes* of the Bridger and Uinta, and *Colodon* of the White River.

Lophiodon has been considered as a very widely spread form in the Middle Miocene of Europe, but it now seems to be the opinion that many species have been wrongly referred to it that should properly be placed with genera *Colodon* and *Helaletes.*

The CHALICOTHEROIDEA is sometimes regarded as a separate suborder, the *Ancyclopoda* not being related directly to the Perissodactyls. They were aberrant animals related on the one hand to the Perissodactyls and on the other to the Edentates. In the structure of the foot there is a striking resemblance to the structure in the great ground sloths, *Gravigrada*, of the late Tertiaries of America. It was five-toed and turned so that the weight of the animal rested upon the outer side of the foot, and the digits terminated in strong claws. The teeth, on the other hand, were strikingly like the teeth of the Perissodactyl series. The suborder, or super-family, had its greatest development in the Miocene and Pliocene times.

Homalodontotherium is from the early Tertiary deposits of Patagonia. The primitive character is indicated by the complete dentition of the animal and the absence of any diastema. The humerus was very short and stout, indicating possible fossorial habits.

Macrotherium is a smaller form from the Middle Miocene of France and Germany. The condition of the teeth indicates a somewhat more advanced type. The fore limbs were much longer than the hind. The best known species was about nine feet in length.

Chalicotherium is the best known form from the United States.

It is found most commonly in the Loup Fork. Many teeth resembling *Chalicotherium* have been named from all parts of the world, notably China, Hungary, and Germany, indicating a very wide range for the genus.

From the Tertiary deposits of South America, in Patagonia, and the Argentine Republic come the remains of many animals that seem to be without representatives in any other part of the world. In some respects they resemble the Perissodactyls and, indeed, one of the orders is regarded by Zittel as a possible family of that group. Their relationships are, however, still too imperfectly known to permit of much discussion. Three orders are known, the *Typhotheria*, *Toxodontia* and *Litopterna* (*Proterotheridae* Zittel). Smith Woodward says they "must be little modified descendants of very primitive eutherian mammals."

Typotheria.—The order is peculiar among the ungulates, in that it possesses a well-developed clavicle. The limbs are unmodified and the dentition is nearly complete.

Pachyrucus and *Typotherium* are the best known genera. The first was somewhat the smaller of the two. The teeth are somewhat rodent-like in appearance and the dentition is not complete. There was a considerable diastema between the enlarged incisors and the premolars, the canines were wanting.

Toxodontia.—The second order of the South American group resembled in many of its characters the first, but lacked the clavicle, and the limbs were modified toward the ungulate type, there being but three toes on the fore and hind feet The animals were much larger than the previous order, reaching nearly the size of the rhinoceros in the genus *Toxodon*. The bodies of the animals were short and stout, and the head was placed on a very short neck low on the body. The two typical genera *Toxodont* and *Nesodon* are both from the Tertiary of South America, but *Nesodon* is from the earliest strata.

Litopterna.—This order was much farther developed than the preceding, and in general appearance could not have been far from that of the modern horse. The primitive condition is indicated by the complete dentition and the stage of develop-

ment of the limbs. There were forms with only a single digit remaining, and others with three, resembling the Perissodactyls in this character, but the same animals had the tarsus built on the Artiodactyl plan so that they can belong to neither group.

Thoatherium and *Proterotherium* are small animals from the Santa Cruz formation of Patagonia. They were monodactyl, the second and fourth digits being either completely lost or greatly reduced in size.

Macrauchenia was much larger than the other two, and resembled the modern camel in size and some of the skeletal characters. The limbs were functionally tridactyl. The genus comes from the Pleistocene deposits of Argentina.

Amblypoda.—This suborder reached its greatest development in the Eocene time and died out at the close of the same period. The members of the suborder were all rather stout animals that reached, near the time of their extinction, the size of an elephant, or nearly so. The brain was very small and almost devoid of convolutions; there were five toes on each of the feet, and the bones of the limbs were complete, *i. e.*, the tibia and the fibula, and the radius and ulna, were separate and perfect. The group is generally divided into two families according to the characters of the teeth, skull and limbs.

Coryphodontidae were animals limited to the lowest Eocene of America, England and France. The greatest number and the most perfect specimens have been obtained from the Wasatch formation of the western part of the United States.

Coryphodon, the typical genus, was a short and rather stout animal about six feet long; the skull was elongated in the facial region with a rather broad muzzle armed with strong incisor and canine teeth; the feet were very short and strong with blunt toes. The brain cavity was very small and limited to a small part of the skull. The surface of the skull was without any bony excrescences or with only very faint ones.

Dinocerotidae: found in the Middle Eocene, Bridger; animals larger than the preceding family, and in general stouter and stronger. The skull was longer and without the anterior

enlargement of the muzzle; the dentition was weaker in that the incisors were lost entirely or in part, and the molars and premolars were small and weak. The canines were greatly enlarged and extended from the jaws as tusks that were protected by a flange of the lower jaw. The top of the skull shows three pairs of bony protuberances that were possibly the bases of horns. The brain was little, if in advance, of that of the *Coryphotondidae*.

Dinoceros (*Unitatherium*).—Characters given in the description of the family.

ARTIODACTYLA.—The families that we shall consider are the *Anthracotheridae*, the *Suidae*, the *Oreodontidae*, the *Hippopotamidae*, the *Camelidae*, the *Anoplotheridae*, the *Tragulidae*, the *Protoceratidae*, the *Cervicorna*, and the *Cavicorna*.

Anthracotheridae.—This is an extinct family that is found chiefly in the deposits of Europe and the East Indies. The earliest member of the group occurs in the Eocene of Europe. During the Miocene time it spread over the whole continent of Europe and over North America. The whole group appears to have died out in the Miocene. The animals were large, about the size of the rhinoceros, and from that down to the size of a pig. The head was long and low, with little development in the cranial region and a consequently small development of the brain. The teeth are of the low multitubercular type that is characteristic of the pig family. The feet have four toes on each foot and the metapodials of the middle pair are not united.

Anthracotherium, Oligocene, of Europe, England, and India, and North America.

Ancodus, Oligocene, of Europe, and North America.

Merycopotamus, Pliocene, of India.

Suidae.—This is a very large group that contains the existing hog. There are many primitive characters in the group, such as the complete dentition, and the generalized multituberculate teeth. The limbs have either four or two toes and the metapodials of the middle pair are not united. The living members of the family are found in Asia, Africa, Europe, and America.

Fossil forms of the group are found in the Eocene of Europe and North America, but the greatest development of the family came from the Pliocene to Recent. The origin of the *Suidae* is not at all well known, but there seems to be little doubt that they are the specialized branch of some carnivorous stem.

Achænodon, from the Bridger Eocene, has very strong canines and the cheek teeth are similar in many respects to those of the primitive *Carnivora*.

Elotherium, from the Oligocene of Europe and the United States, White River, is one of the ancestral forms. The head is long, the posterior teeth are multitubercular, the premolars are conical, and the canines and incisors are long and well fitted for grasping. The limbs were peculiarly long, and altogether the animal seems to have been a rather vicious type of carnivorous hog that had the running powers of a deer.

Platygonus, from the Pliocene and the Pleistocene of the United States, was a very small form that seems to have been the direct ancestor of the peccary.

Sus, the true hog, appeared in Europe and Asia, in the Upper Miocene and has continued ever since. There is no native member of the genus in the Americas.

Hippopotamidae.—The Hippopotamus is not known earlier than the Pliocene, and occurs in deposits of that age in England and in India. The existing forms are confined in Africa.

Oreodontidae.— This is an extinct group that is confined to the Miocene and the lower Pliocene of the United States. It is primitive in all of its characters; the dentition is complete and the fore limb has five digits; the metapodials are not united. One peculiar thing is that the anterior lower premolar tooth passed forward and acted as the canine, while the canine assumed the aspect and the function of an incisor. The sense of hearing was very acute, the bulla of the ear reaches, in some of the later forms a very large size. The animals were all small, never reaching a size larger than that of a Newfoundland dog, and in most cases were much smaller. From the manner of the occurrence of their remains it seems that they lived near the banks

of the lakes or streams and gathered together in great herds. The time of their greatest development was the Oligocene, and in the beds of the White River deposits the remains are found in the greatest abundance.

Protoreodon.—Uinta.

Agriochoerus.—White River, a peculiar form that had the toes terminated in sharp claws like the Sloths.

Oreodon.—White River.

Leptauchenia and *Cyclopedius.*—Upper Miocene, Deep River.

Camelidae.—The camels seem to have developed first on the North American continent in the Middle Eocene, Uinta, and Bridger, and to have died out in the Pliocene. They are peculiar in the much elongated head and the deficient anterior dentition. In the older forms the metapodials are separate as in the families already described, but in the later ones the two are joined and only a thin layer of bone separates the two medullary cavities.

In South America during the Pliocene time there were developed a large number of forms that became extinct, with the exception of the existing Llama. The genus *Camelus* appeared in Asia in the Lower Pliocene without known forerunners, and in North Africa at the beginning of the Pliocene.

Leptotragulus.—Unita.

Poebrotherium.—White River.

Protolabis.—Loup Fork.

Procamelus.—Loup Fork.

Anoplotheridae.—Small extinct forms that were developed in the Eocene of Europe and died out in the lower Miocene. They seem never to have extended beyond the limits of the continent of Europe. They were among the first to develop the selenodont form of teeth that is the characteristic form of the deers and the most of the ruminants.

Anoplotherium.—Eocene.

Dichobune.—Eocene.

Xiphodon.—Eocene.

Cænotherium.—Miocene.

Tragulidae.—Small forms that began in the Eocene of Europe and spread over nearly all parts of the world in the Miocene and the Pliocene. *Tragulus* of the East Indies and *Hyœmoschus* of the west African region are still living members of the group.

The group is highly specialized. The median metapodials alone are functional, the second and fifth are reduced to mere splints at the upper and lower ends of the middle pair. The carpals and tarsals are united in some forms and the metapodials are elongated and united in many of the forms to a cannon bone. The elongation of the limb, due to the length of the metapodials indicates the great running and leaping powers of the form. The upper incisor teeth are wanting and in the males the upper canine is elongate and appears outside of the mouth as a long tusk.

Lophiomeryx.— Europe, Upper Eocene.

Prodremotherium.— Europe, Upper Eocene. Remarkable for the slender skeleton and the length of the limbs.

Gelocus.— Europe, Oligocene.

Dremotherium and *Amphitragulus.*—Lower Miocene, Europe.

Dorcatherium.— Miocene, Europe and Asia.

Leptomeryx and *Hypertragulus.*— North America, Miocene.

Tragulus appeared in the Pliocene of Asia, and *Hyaemoschus* is unknown from fossil remains.

Protoceratidae.—A small family resembling in many respects the *Tragulidae* of the old world. The group is confined to the upper part of the White River formation of the United States. There is only one well-known genus, the *Protoceras*, an animal that resembled the modern antelope, probably, as much as any recent form. The male is peculiar in the fact that the skull bore two or three pairs of horn cores. The female was without horns.

Cervicorna.—This essentially modern group appears in the Miocene of Europe and North America and has a considerable number of the members still living. The males have, in nearly every case bony horns that are shed every year, differing in this respect from the succeeding group in which there is a permanent horn core, and the horn proper is not shed. The upper incisors

are deficient or entirely absent, and the upper canines are either absent, small, or enlarged as in the *Tragulidæ*. The carpals and the tarsals are anchylosed in some forms and the metapodials are united to form a cannon bone. The whole structure of the skeleton indicates the lightness and the speed of the deer tribe.

Blastomeryx.— North America, Miocene and Pliocene.

Paleomeryx.— Europe, Miocene.

Helladotherium.— Europe and Asia, Upper Miocene. This form with the *Samotherium* of Europe are interesting as being the ancestors of the giraffe, *Camelopardalis*, which is found in the same deposits and then disappears from the record to appear again in the Recent in Africa.

Sivatherium and *Bramatherium* are large forms, strikingly resembling the moose, which are known from the Miocene deposits of India and unknown since.

Most of the modern forms of the family seem to have appeared in the Pliocene and their remains are especially well preserved in the European deposits, but not until the Pleistocene time do the deposits indicate anything like the profusion of numbers and the widespread distribution of the group that obtains at present.

Cavicornia.— The group is in few particulars different from the *Cervicornia*. The horns are not deciduous or bony, they are present in both sexes. The teeth are similar in many respects, but the upper canine is always lacking as well as the upper incisors. The metapodials are always united to form a cannon bone and the lateral digits are the merest rudiments or are completely absent. In general the skeleton is very similar to that of the preceding group, but in many of the forms it is much more robust. One thing characteristic of the group is the width of the brow. Where the horns are set close together in the *Cervicornia*, in this group they are wide apart, a condition that reaches its greatest development in the *Bovidae*, the cows and buffaloes. It is of interest to note that the same loss of the enamel which took place on the upper surface of the teeth of the *Equidae* also took place in the *Artiodactyla*, and the later

forms have the enamel entirely removed from the tops of the tubercles and the spaces between the walls filled up with a softer and more rapidly wearing cement.

Three general divisions may be recognized, the antelopes, the sheep and the bovine tribe. The oldest of these, the antelopes, appeared in the Miocene of Europe and southern India. They seem to be derived directly from the *Cervulinae*, a subfamily of the *Cervicornia* represented by *Dremotherium* and *Amphitragulus*. During the Pliocene the three groups were differentiated.

Pliocene.	Antilopinae. Ovinae. Bovinae.
Upper Miocene.	Antilopinae.
Lower Miocene.	Cervulinae. Dremotherium and Amphitragulus.

Proboscidea.—The origin of this suborder is not at all well understood, the first members of the group are found in the Miocene time and in all the essential characters are as well developed as the most advanced of the living forms. In many of their characters the *Proboscidea* are very primitive ; the structure of the feet and of the carpus and tarsus, the structure of the limbs and other parts of the body, are such as are found in the earliest ungulates. The development of the proboscis and the correlated shortening of the neck and the development of the peculiar dentition are the only characters that define the group. The most characteristic feature is the development of the incisor teeth as tusks which in some forms occur in both the upper and the lower jaws, in others in the lower jaws, and in the most modern forms in the upper jaws. In the earliest forms there were many teeth in the jaws, each one with strong transverse ridges completely covered with enamel ; in the advance of the group the ridges on the teeth seemed to multiply until they became very numerous, and at the same time the enamel disappeared

from the top of the ridges, leaving the softer dentine exposed, which wore away more rapidly than the enamel and left strong, grinding ridges such as are found in the horse. With the advance in the structure of the teeth appeared the degeneration of the dentition as a whole, so that the modern elephant has never more than one cheek tooth at a time in the jaw; the teeth appear successionally, the anterior one first and so backwards during the life of the animal.

Dinotherium is the earliest known member of the group. It was characterized by the development of a pair of down-curving tusks in the lower jaw and a complete absence of incisors in the upper jaw. There was a more or less complete dentition, the jaw containing two premolars and three molars. The single complete skull known is about three feet long. The genus is known from the Miocene of Bohemia and from the Pliocene of Central Europe and India. It is unknown from America.

Mastodon differed from the preceding in the presence of fewer molar teeth and in the presence of tusks in both the upper and lower jaws or in the upper jaw alone. The molar teeth exhibit many variations in form, but in general the surface has a tendency to be distinctly tuberculated, the transverse ridges multiplying and dividing into outer and inner halves. In size the animal was nearly as great as the elephant. It was very common in the later Tertiary and forms have been discovered in formations as early as the Middle Miocene in Central Europe. In the Pliocene the genus seems to have reached a wonderful development and to have ranged over the greater part of the world; forms have been discovered in nearly every part of the world that man has visited. Near the close of the Pliocene it disappeared from Europe, but is found in the Pleistocene of America, sometimes associated with flint implements.

CARNIVORA.— The order *Carnivora* is one of the best known from the fossil forms. In the earliest Eocene they approach the *Condylarthra* to an extent that makes it difficult to tell the lines of the Ungulates and the Unguiculates (claw-bearing forms)

apart. The earliest of the *Carnivora* are placed in a suborder, the *Creodonta* opposed to the suborder *Carnivora vera* which includes the recent Carnivores and their immediate ancestors.

Creodonta.—These animals show their approach to the carnivorous type by the development of specialized cutting teeth, the appearance of claws on the feet and the assumption of the general form of the modern carnivores. Recent investigations show that this suborder is perhaps the most primitive of the modern mammals and is to be considered the ancestor of the ungulate type. Osborn, in a discussion of the questions of paleontology, said: "The most primitive type of Condylarth (*Euprotogonia*) and of Amblypod (*Pantolambda*) as recently studied by Osborn and Matthew, strongly reinforces the hypothesis first enunciated by Cope, *that the source of the Ungulata is to be found in the Creodonta.* Upon the other side of the great Mammalian tree, the numerous branches of Unguiculates or primitive clawed types also have converged towards a Creodont ancestry, as seen especially in the characters of the Ganodonta, or ancestral Edentates, and of the Rodentia, if Matthew's supposition proves to be correct also of the Tillodontia. Thus all these groups should be added to the Carnivora as Creodont derivatives. The Carnivora extend back into Creodont prototypes; but, as in the case of the Artiodactyla and the Perissodactyla, the actual points of contact or links between the two divisions are yet to be discovered." He extends the discussion to the position of the Creodonta with relation to the primates. He says: "The point of contact of the primates with the Creodonta is still entirely wanting, but their relations appear to be here rather than with the Insectivora.

"In spite, therefore, of the many remaining deficiencies or absence of links in our paleontological evidence, it has none the less come about *that the Creodont type takes the central position which was assigned by Huxley in 1880 to the Insectivora,* for the known Creodonta are more generalized and more central than any other of the known Insectivora, fossil or living, the known Insectivora showing a very considerable specialization, especially

in their dental succession, which places them apart as a distinct side phylum. This does not affect the derivation of the Creodonta themselves from stem forms of unspecialized Insectivora existing in the Jurassic period, the characters of which are seen in the *Insectivora Primitiva*, or placentals of the Stonesfield Slate and Purbeck periods."

The *Creodonta* are generally divided into eight families, which are here arranged as nearly as possible in the order of their evolution, which was directed toward the development of more perfect sectorial teeth and more and deeper convolutions on the surface of the brain.

Arctocyonidae: from the lowest Eocene of the United States, Puerco and Wasatch and the lowest Eocene of France.

Oxyclænidae: from the lowest Eocene of the United States.

Triisodontidae: from the lowest Eocene of the United States.

Mesonchyidae: from the Lower and Middle Eocene and possibly from the Miocene of the United States.

Proviverridae: from the Eocene of Europe and the United States.

Paleonictidae: from the Lower Eocene of the United States. This family is of some interest as containing the possible ancestor of the pinniped group of the true Carnivores.

Hyænodontidae: from the Eocene to the Miocene of Europe and America. This family has well-developed teeth of the sectorial type and approaches very close to the true carnivores.

Miacidae: from the Eocene of the United States. This family so closely approaches the modern carnivores that they have been placed among them by certain authors.

From the Lower Tertiary deposits of South America, Patagonia, come many forms that are undoubtedly Creodonts but of doubtful position in the suborder; by some authors they are placed among the *Hyænodontidae*, and by others they are placed in a separate group, the *Sparrassodonta*. The best known forms are *Prothylacinus* and *Borhyæna;* they are very similar in some respects to the carnivorous Marsupial, *Thylacinus*, of Tasmania.

The *Carnivora vera* are distinguished by the larger size of the brain with its deeper convolutions and the development of a single tooth in each jaw, the fourth premolar in the upper jaw and the opposing first molar in the lower jaw, as sectorial teeth. The suborder is generally divided into two groups : the *Fissipeda* or land living forms and the *Pinnipeda*, seals, walruses, etc.

Fissipeda. — Seven families are recognized, the *Canidae*, *Ursidae*, *Procyonidae*, *Mustelidae*, *Viverridae*, *Hyænidae* and *Felidae.*

Canidae.— The dogs appeared in the Upper Eocene of Europe and the Lower Miocene of the United States. They are descendants, probably, of the Proviverrine branch of the *Creodonta.* The development of the dogs has been toward the improvement of the feet as organs of locomotion; the early forms had five toes on both the fore and the hind feet, but in the modern forms the first digit is wanting on the front foot and often on the hind foot as well. The teeth have developed from low crushing forms to the more typical carnivorous condition with the specialized carnassials. Typical forms are :

Cynodictis and *Cephalogale*, Upper Eocene, Europe.

Amphicynodon, Oligocene, Europe.

Amphicyon and *Galecynus*, Miocene, Europe.

Daphænos and *Oligobunis*, North American Miocene.

The recent forms appeared in the Pliocene of Europe, Asia and North America, and in the Pleistocene of Africa and South America.

Ursidae.— The bears are distinguished by the plantigrade feet and the low multitubercular teeth without the specialized carnassials. They appeared in the Middle Miocene of Europe in the genus *Hyænarctos* and not before the Pleistocene in the other countries when the existing genera were developed.

Procyonidae.— The coons occupy a small place somewhere between the dogs and the bears. They were developed some time in the Pliocene and are today confined to the American and the South Asian regions. They are known from the Loup Fork beds of the United States.

Mustelidae.— The weasels and otters are among the most

specialized of the *Carnivora.* The first live almost entirely upon blood drawn from the veins of their victims and the second are aquatic in habit and great eaters of fish. They began their development in the upper Eocene and in that time and the Miocene a large number of forms were developed in Europe. After the Miocene they spread out and the deposits of all parts of the world, with the exception of Australia, are rich in their remains.

Viverridae.—A small group of cat-like animals confined to Africa, Asia and Southern Europe. They originated in the Eocene of Europe and only as late as the Pliocene appeared in others countries.

Hyænidae.—The hyænas are somewhere between the cats and the bears, the teeth are partly sectorial and partly crushing in form. They appeared in the Upper Eocene of Europe and Asia and are now known from those deposits with the addition of North Africa. *Hyænictis* is one of the first forms. It is from the Miocene of Europe and Asia.

Felidae.—The cats reach, perhaps, the highest point of the development of the *Carnivora.* The teeth are highly specialized; the molars seem to show a tendency to grow less in number and to assume more and more the form of the feline carnassials which are the highest type of that tooth form developed. The fore feet are modified to serve as organs of prehension as well as locomotion. The canine tooth reaches enormous proportions in some forms, and there is a process on the lower jaw to protect them as in the *Dinocerata.* They originated in the Upper Eocene and rapidly spread all over the world. The Oligocene, White River, of the United States is especially rich in the remains of these forms.

Eusmilus.—Upper Eocene of Europe.

Hoplophoneus, Dinictis, Nimravus and *Pogonodon.*—White River, United States.

Machairodus.—Pliocene, Europe, Asia, and the Americas. This form is remarkable for the great length of the upper canine. It was so long that it is possible that the animal could

not open its mouth wide enough to bring the teeth into play. It has been suggested that the teeth were used to aid it in climbing trees.

The existing genera of the cats were developed in the Pliocene and Pleistocene.

Pinnipeda.—The water living carnivores seem to have sprung, as has been suggested, from the Creodont *Patriofelis.* The existing families can be traced back as far as the Pliocene but beyond that there is nothing to connect them with the early forms. Fragmentary skeletons of seals and walruses have been found in the Pliocene of Europe and America.

INSECTIVORA.—The Insectivores are among the least changed of all the Mammals from their prototypes of the earliest Tertiary. The brain, carpus and dentition all present characters that are found in the Creodonts. Many of the existing families are found in the Eocene.

CHIROPTERA.—The bats are known from deposits as early as the Eocene in Europe and America, but nothing is known of their ancestry; the fossil genera, including those extinct, are very similar to the living forms.

RODENTIA.—The order is characterized by the absence of the canine teeth, the development of two incisors in the upper and the lower jaws as gnawing teeth which grow from persistent pulps and the arrangement of the articular condyle so that the lower jaw can slide backward and forward in the act of grinding up the food. There are many primitive characters in the group which is a remarkably persistent one, well-defined rodents being known from the early Eocene. Three suborders are known: the *Tillodontia*, *Duplicidentata* and the *Simplicidentata.*

Tillodontia.—These are forms that are known from the Eocene deposits of Europe and America. In these the canines are still preserved as rudiments, and there are sometimes more than the single pair of incisors in the lower jaw.

Esthyonx from the Wasatch and Bridger series of the United States is the earliest form known. A fragmentary skull from

the London Clay seems to indicate the presence of a related form in Europe.

Tillotherium from the Bridger of the United States is the largest form known; the skull measured about a foot in length. The developed incisor teeth are of large size, and the second pairs of incisors and the canines are even smaller than in the preceding genus.

Duplicidentata.—This group contains the hares and rabbits. They seem to have been developed about the Middle Miocene, *Paleolagus*, White River. During the Pliocene they spread over all of Europe and North and South America.

Simplicidentata.—This group is far larger than the preceding; it contains the rats, mice, squirrels, and all the remaining forms of the rodents. None of the forms appear before the Miocene, and during that time and the Pliocene differentiated and spread all over the world.

PRIMATES.—The order is divided into two suborders, the *Lemuroidea*, containing the lemurs, and the *Anthropoidea*, containing the apes and man.

Among the primitive lemurs are many forms which are so clearly intermediate between the two suborders that they must be regarded as the direct ancestors of the *Anthropoidea*. The living lemurs are confined to the island of Madagascar and to parts of Africa and southern Asia. In the Miocene and Eocene times they seem to have spread over the greater part of Europe and North America; they became extinct in the latter countries about the end of the Miocene time. Among the most important forms of the lemurs are *Anaptomorphus*, *Adapis* and *Megaladapis*.

Anaptomorphus is from the Wasatch Eocene of Wyoming; related forms are known from the lower Eocene of France and England. The animal exhibits the very large cerebral hemispheres that are characteristic of all the Primates and thus indicates the starting point of the specialization in the nervous system that has culminated in man.

Adapis is from the Lower Eocene of Europe; a closely related form is *Tomitherium* from the Eocene of New Mexico.

Megaladapis is a very large form from the post-Pleistocene of Madagascar. The skull was about two feet long. The animal seems to have lived in the island as late as the seventeenth century.

Anthropoidea.—The true apes do not appear until the middle of the Miocene; in Europe they seem to have extended over a large part of the continent as late as the Pliocene time, and one genus still exists upon the rock of Gibraltar. The genera of the apes multiply so rapidly that it is not possible to trace the development of the forms in any limited paper. It will perhaps suffice to note their occurrence in the Middle Miocene of France, the Pliocene of Germany, the Pliocene and Pleistocene of India and the early Tertiary of Patagonia.

In regard to the derivation of the human family, *Hominidae*, from the Primates Cope says (*Primary Factors of Organic Evolution*, chap. 11, p. 157. The phylogeny of man): "To return to the more immediate ancestry of man I have expressed and now maintain as a working hypothesis that all the Anthropomorpha were descended from the Eocene lemuroids. In my system the Anthropomorpha includes the two families Hominidæ and Simiidæ. The sole difference between these families is seen in the structure of the posterior foot, the Simiidæ having the hallux (great toe) opposable, while in the Hominidæ the hallux is not opposable. . . . . " "It is then highly probable that Homo is descended from some form of the Anthropomorpha now extinct, and probably unknown at present, although we do not yet know all the characters of some extinct supposed Simiidæ, of which fragments only remain to us."

Smith Woodward says of the earliest men: "Most of the evidence for the existence of the human race in the pre-historic past consists in traces of intelligent handiwork revealed by stone and other implements. A few discoveries in the old world, however, are worthy of consideration.

"The oldest known traces of a man-like skeleton seem to be an imperfect roof of a skull, two molar teeth, and a diseased femur, from a bed of volcanic ash containing the remains of

Pliocene mammals, near Trinil, in central Java. These are believed to belong to one animal which has received the name of *Pithecanthropus erectus*. The capacity of the brain-case is estimated to have been about two-thirds the average of that of man: the forehead is very low; and the supraorbital ridges are prominent. The inclination of the nuchal surface of the occiput is considerably greater than in the Simiidæ. The femur measures 0.455 m in length, and denotes an upright gait.

"The oldest human skeletons of which the geological age is determined with certainty, are two from the cavern of Spy, near Namur, in Belgium. These were found in association with remains of the mammoth and other Pleistocene mammals beneath a layer of stalagmite, which had never been disturbed, and which was also covered with earth containing bones of the same extinct quadrupeds. The skeletons, therefore, could not be the result of a comparatively recent burial, but were proved to have been contemporaneous with the associated animals and Palæolithic flint implements. They are essentially human in every respect, but seem to represent a race inferior in skeletal characters to any now existing. They are small, but powerfully built. The forehead is low; the supraorbital ridges are very prominent; and the chin is remarkably retreating. The radius and ulna are unusually divergent in the middle. The femur is somewhat bent, and the tibia is comparatively short, so that the leg cannot have been quite upright in walking. This type is now generally known as the *Neanderthal race*, the roof of a similar skull having been found associated with other fragmentary remains so long ago as 1857 in a cavern in the Neanderthal between Düsseldorf and Elberfeld, Germany."

In closing the discussion of the mammals, it is well to draw attention to the idea so forcibly set forth in Lydekker's book, *Geographical History of the Mammalia*, that all the mammals had a northern origin, and have attained their present position by gradual migration toward the south. Though the theory is still far from being proven, it should be of great interest to the student of geology because of the possibilities it presents for an

interpretation of climatic and land-mass conditions in the Tertiary time. Throughout the book evidence is constantly adduced to show the strength of the author's position. I shall quote merely enough of the introduction to give an idea of the theory.

Upon page 7 the author says: "There is a considerable probability that at least a very large proportion of the animals that have populated the globe in the later geological epochs originated high up in the northern hemisphere, if not, indeed, in the neighborhood of the pole itself (which is known to have enjoyed a genial climate during the Tertiary period), and that they gradually migrated southwards in a series of waves, probably under pressure of the development of new and higher types in high latitudes; and it is to such southerly migrations that the present marked differentiation of the fauna of different parts of the earth's surface is chiefly due. Whether such a northerly origin held good for the terrestrial life of the Secondary epoch, there are no means of determining; but it would appear that the higher animals (which were chiefly reptiles) of that epoch were very similar throughout the world, and that the differentiation of faunas had scarcely, if at all, commenced." . . . . "With mammals the case is very different. The earliest known forms, which date from the Triassic and Jurassic rocks, are chiefly marsupials and forms apparently allied to the monotremes, and it is probable that most of the descendants of these, as is more fully indicated in the sequel, migrated southwards during the early part of the Tertiary epoch, to find in Australasia a refuge from the competition of higher forms. Of the higher placental mammals, none of the modern types make their appearance before the Oligocene and Miocene periods, while many do not antedate the Pliocene. Their southern migrations accordingly took place later on in the Tertiary period, one of the earliest movements being the wandering of lemuroids, insectivores, and civet-like carnivores into South Africa and Madagascar. On the other hand, many other higher types, such as the hippopotami, giraffes, and antelopes, which were abundant in Europe and southern

Asia during the Pliocene, only left their more northern homes to find a permanent abiding place in Africa at a very late epoch in the earth's history."

E. C. Case.

References.—Other than the books already referred to, the student will find the most helpful literature in the files and current numbers of *The American Journal of Science, The American Naturalist*, which contains a number of separate articles upon the different groups, by the late Professor Cope, the *Proceedings of the Philadelphia Academy of Science*, the *Proceedings of the American Philosophical Society*, *The American Geologist*, and *The Kansas University Quarterly*.

EDITORIAL

A PRELIMINARY circular of the French Committee of Organization for the Eighth Session of the International Geological Congress announces the date of the meeting to be held in Paris in 1900. The meetings will be opened on the 16th of August and will be closed on the 28th. They will be held in a building connected with the Exposition, and the hours will be so arranged as to give the members opportunity to visit the Exposition.

Field excursions are to be made a prominent feature of the session and will take place before, during, and after the meetings. These excursions are to be of two kinds, *general* and *special.* The first will be open to as large a number of members as possible, who may be taken to localities where hotel accommodations are adequate. The special excursions are intended for specialists, and since they may necessitate the visiting of regions poorly provided with hotels, the number of members who may participate in each excursion is limited to twenty. To compensate for the small number of geologists admitted to any one of these excursions, the number of excursions is increased to nineteen. This arrangement promises to be a satisfactory solution of the difficult problems connected with the geological excursions, which form so valuable a factor in the organization of the congress.

Of the general excursions three are announced:

1. Tertiary Basins of Paris, conducted by MM. Munier-Chalmas, Dollfus, L. Janet, and Stanislas Meunier.

2. Boulonnais and Normandie, conducted by MM. Gosselet, Munier-Chalmas, Bigot, Cayeux, Pellat, Rigaux — 10 days.

3. Central plateau of France, conducted by MM. Michel-Lévy, Boule, Fabre — 10 days.

The nineteen special excursions include:

I. Ardennes, conducted by M. Gosselet — 8 days.

II. Picardie, conducted by MM. Gosselet, Cayeux, Ladrière — 6 days.

III. Bretagne, conducted by M. Barrois — 10 days.

IV. Mayenne, conducted by M. Oehlert — 8 days.

V. Turonian Types of Touraine and Cenomanian Types of Mans, conducted by M. de Grossouvre — 6 days.

VI. Faluns of Touraine, conducted by M. Dollfus — 4 days.

VII. Morvan, conducted by MM. Vélain, Peron, Bréon — 10 days.

VIII. Coal Basins of Commentry and of Decazeville, conducted by M. Fayol — 7 days.

IX. Massif of Mont-Dore, Chain of Puys, and Limagne, conducted by M. Michel-Lévy — 10 days.

X. Charentes, conducted by M. Glangeaud — 8 days.

XI. Basin of Bordeaux, conducted by M. Fallot — 6 days.

XII. Tertiary Basins of the Rhône, Secondary and Tertiary Terranes of the Basses-Alps, conducted by MM. Depéret and Haug — 12 days.

XIII. Alps of Dauphiné and Mont Blanc, conducted by MM. Marcel Bertrand and Kilian — 10 days.

XIV. Massif of Pelvoux (High Alps), conducted by M. Termier — 10 to 12 days.

XV. Mont Ventoux and mountain of Lure, conducted by MM. Kilian, Leenhardt, Lory, Paquier — 10 days.

XVI. Basse-Provence, conducted by MM. Marcel Bertrand, Vasseur, and Zürcher — 10 days.

XVII. Massif of Montagne-Noire, conducted by M. Bergeron — 8 days.

XVIII. Pyrénées (crystalline rocks), conducted by M. Lacroix — 10 days.

XIX. Pyrénées (sedimentary rocks), conducted by M. Carez — 10 days.

Further notice of the excursions and a guidebook relating to them will be issued early in 1900. J. P I.

SUMMARIES OF CURRENT NORTH AMERICAN PRE-CAMBRIAN LITERATURE[1]

Boss[2] describes the dikes associated with the ore deposits of the Gogebic iron range. They are dioritic and more or less altered; they are approximately at right angles with the dip of the formation they cut, and the greater number of them have an average easterly dip of 15° to 18°—sometimes they are folded in such a manner as to form long synclinal basins with eastward pitch. In a majority of cases mining exploitation has shown a succession of dikes, one below the other, and ferruginous quartzite of varying thickness immediately underlying each dike and forming the cap of the succeeding deposit of ore.

Comment.—The dikes have been shown by Irving and Van Hise[3] to be diabase, rather than diorite. With this exception, the above observations are in accord with and confirm those of Irving and Van Hise in this area, and except in a few details nothing new is presented. For a comprehensive discussion of the position of the dikes and their relations to the ore bodies the reader is referred to Monograph XIX of the United States Geological Survey.

Wadsworth[4] describes the origin and mode of occurrence of the Lake Superior copper deposits, and the age of the copper-bearing series. A reëxamination of the Douglass Houghton and Hungarian River areas shows that the Eastern Sandstone passes under the lavas with increasing dip, and that the junction is not a fault junction, but that of a lava flow upon an underlying soft sand and mud. It is held that the Eastern Sandstone is of Potsdam age, and underlies the copper-bearing series, the first lava of that series having flowed out upon the

[1] Continued from p. 854, Vol. VI, JOUR. GEOL.

[2] Some dike features of the Gogebic iron range, by C. M. Boss, Trans. Am. Inst. Min. Engineers, Vol. XXVII, 1898, pp. 556–563.

[3] The Penokee-Gogebic iron-bearing series of Michigan and Wisconsin, by R. D. IRVING and C. R. VAN HISE: Mon. U. S. Geol. Surv., No. XIX, 1892.

[4] The origin and mode of occurrence of the Lake Superior copper deposits, by M. E. WADSWORTH: Trans. Am. Inst. Min. Engineers, Vol. XXVII, 1898, pp. 669–696.

sandstone. The basaltic rocks forming the Bohemian Mountains present phenomena which indicate their eruption subsequent to the formation of the main deposits of the region, although the question is as yet open. Subsequent to the deposition of the Keweenawan a fissure was formed near the contact of the Eastern Sandstone and the lavas, along which normal faulting occurred, the copper-bearing series forming the overhanging side of the fault. As to the nature of the displacement, however, more evidence is needed. The copper occurs in fissure veins, in melaphyres, and in conglomerates.

Comments.—That the Keweenawan was deposited on the Eastern Sandstone was held by Wadsworth before the publication of Irving's[1] report on the copper-bearing series in 1883. In his report Irving presented evidence to show that this could not be the case, but that the sandstone is post Keweenawan; and later, in 1885, Irving and Chamberlin[2] in a more comprehensive discussion of the relations of the Keweenawan to the Eastern Sandstone, proved still more clearly the post-Keweenawan age of the Eastern Sandstone. Subsequently, in 1893, Wadsworth took the view that the Keweenawan formed the lower part of the Potsdam, and explained the phenomena on the theory that the Eastern Sandstone, instead of being one sandstone, may contain two or three sandstones of different ages. In the article above reviewed Wadsworth has gone back to his earlier view. However, he has not yet met the arguments so clearly stated by Irving and later and more comprehensively, by Irving and Chamberlin.

Berkey[3] describes and maps the geology of the St. Croix dalles of Wisconsin and Minnesota. Keweenawan eruptives are exposed at numerous localities, and particularly along the river, where, by their erosion, they have formed the dalles of the St. Croix River. The dip is about 15° to the south, which would give a thickness to the rocks in sight of 4000 feet. At several localities the Basal Sandstone unconformably overlies the Keweenawan eruptives with visible contacts, the

[1] The copper-bearing rocks of Lake Superior, by R. D. IRVING: Mon. U. S. Geol. Surv., No. V, 1883.

[2] Observations on the junction between the Eastern Sandstone and the Keweenaw series on Keweenaw Point, Lake Superior, by R. D. IRVING and T. C. CHAMBERLIN: Bull. U S. Geol. Surv., No. XXIII, 1885.

[3] Geology of the St. Croix Dalles, by C. P. BERKEY: Am. Geol., Vol. XX, 1897, pp. 348–383, and Vol. XXI, 1898, pp. 139–155, 270–294.

Basal Sandstone including the sandstone and shale series between the Keweenawan and the St. Lawrence shales.

Winchell[1] discusses the significance of the fragmental eruptive débris at Taylor's Falls, Minn. This has heretofore been regarded as a conglomerate resting unconformably upon the Keweenawan. As a result of recent field work by Mr. C. P. Berkey, it is believed that this conglomerate may be separated into two conglomerates, an upper one at the base of the upper division of the Cambrian, and a lower one at the base of the lower division. The latter would come within the Keweenawan, as this term is used by Irving and other writers, and would separate this series into two parts.[2] The later conglomerate rests directly upon the earlier one, leading to the previous confusion of the true relations. Similar conglomerates found in the Keweenawan at several points between Duluth and Grand Portage have led to the conclusion that the Keweenawan may be divided into two great series, separated by conglomerate and quartzite which reach a thickness of several hundred feet. The lower series has been included in the Norian, and the upper series comprising the sedimentaries and the eruptives above them, has been called Keweenawan, the Keweenawan forming the lower division of the Cambrian.

Comments.—While the conglomerate within the Keweenawan at this locality has not before been noted, the occurrence of many conglomerates at other localities in the middle and upper part of the Keweenawan has been mapped and described by the Michigan and United States geologists, as a glance at Marvin's Eagle River section[3] and Irving's general report[4] on the Keweenawan will indicate. Instead of one conglomerate, there are a dozen conglomerates at different horizons. However, these conglomerates are composed almost without exception of local material, derived wholly from contemporaneous lava flows, and are held to mark very insignificant breaks in the series. As seen from Winchell's description, the Taylor's Falls conglomerate belongs to this class. The United States geologists, recognizing the

[1] The significance of the fragmental eruptive débris at Taylor's Falls, Minn., by N. H. Winchell: Am. Geol., Vol. XXII, 1898, pp. 72–78.

[2] In a recent paper, above summarized, Mr. Berkey (Am. Geol., Vol. XX, p. 381) takes the view that the lower conglomerate is a flow breccia of the igneous rocks.

[3] Geology of Michigan, 1873, Vol. I, Part II, Copper-bearing rocks, pp. 117–140.

[4] Copper-bearing rocks of Lake Superior, Mon. V, U. S. Geol. Surv., 1883.

local character of the conglomerates, have considered the series including them as a unit, and, regarding the hiatus at the top of the series as much more profound than that at the bottom, have included the series in the Algonkian, rather than in the Cambrian. Winchell and many of the Canadian geologists, on the other hand, have recognized but one conglomerate within the Keweenawan, and, giving this undue significance, have extended the Cambrian downward to this conglomerate, thereby including in the Cambrian the profound unconformity separating the Keweenawan series and the fossil-bearing Cambrian. If Winchell's reasoning be carried to its logical conclusion, wherever a conglomerate is found within the Keweenawan, the series must there be divided, and in place of one series, we shall have many series, a division which cannot be considered reasonable. It appears, therefore that Winchell's division of the Keweenawan into two series, on the basis of local conglomerates such as the one described from Taylor's Falls, is purely arbitrary, and furthermore, by referring his upper division to the Cambrian, the profound unconformity known to exist between the true Cambrian and the Keweenawan is practically ignored.

Winchell[1] discusses the Archean greenstones of Minnesota, which he considers the oldest known rocks, representing the original crust of the earth. The greenstones are divisible into two parts, one igneous and the other clastic, the latter succeeding the former with a confused, and apparently sometimes conformable superposition, somewhat as surface eruptive rocks might be superposed, in the presence of oceanic action, upon a massive of the same nature at the same place. The clastic portions of the greenstones vary to more siliceous rocks, constituting great thicknesses of graywackes, phyllites, and conglomerates, and as such have been converted by widespread metamorphism into mica-schists and gneisses.

As the Laurentian gneisses and granites cut the schists and sedimentary gneisses they are also younger than the bottom greenstones.

The metamorphic schists and gneisses seem to be representative of the sedimentary portion of the Lower Laurentian of Canada, while the igneous granite and gneisses are as plainly a general parallel of the igneous portion of that series. It follows, therefore, that the Canadian Laurentian is, as a whole, of later date than the greenstones, if the

[1] The oldest known rock, by N. H. WINCHELL: Proc. Am. Assoc. Adv. Sci. Vol. LXVII, 1898, pp. 302, 303 (Abstract).

succession is the same as in the Northwest, and that the greenstones should be considered the bottom rock of the geological scale.

Winchell[1] attempts to explain the origin of the Archean igneous rocks. From field evidence and petrographic discriminations and associations, it is believed that the alkaline magma from which the igneous rocks were derived is the result of aqueo-igneous fusion of the fragmentals of the Archean itself; that when deeply buried, under heat and pressure, the Archean clastics were rendered plastic, penetrating openings in the adjacent and superjacent strata; and that when the plastic mass was not moved from its place it was simply recrystallized *in situ*.

The clastic rocks must have been derived from the basal greenstone, which is considered representative of the original crust of the earth. The presence in such clastics of sufficient potassa and silica to yield upon fusion the granitic magmas is explained on the hypothesis that they must have come from the waters depositing the fragmentals, and primarily from the atmosphere, in its condition normal to the Archean age, just following the congealing of the first crust.

While numerous instances of such transition from clastic to igneous rock have been noted in Minnesota, there has been a careful study of but one. That was the case of the granite and porphyry which intrude the clastics at Kekequabic Lake.

Winchell[2] presents some additional points on the geology of northeastern Minnesota.

The Laurentian includes, in Minnesota, an acid crystalline schist of sedimentary origin, and a massive igneous rock, although the igneous rock is younger than the crystalline schist portion, and should have a different designation. The conclusions reached are that: (1) the sedimentary Laurentian is a crystalline condition of sedimentary strata, which are conformably a portion of the sedimentary schists; (2) the igneous Laurentian is the result of a more intense metamorphism, carried even to fusion of some strata. These conclusions result particularly from the study of a section from Tower northward, through Vermilion

[1] The origin of the Archean igneous rocks, by N. H. WINCHELL: Proc. Am. Assoc. Adv. Sci., Vol. XLVII, 1898, pp. 303, 304 (Abstract). Also Am. Geol., Vol. XXII, 1898, pp. 299–310.

[2] Some new features in the geology of northeastern Minnesota, by N. H. WINCHELL: Am. Geol., Vol. XX, 1897, pp. 41–51.

Lake, and of an area on the west side of Outlet Bay, in the corners of sections 13, 14, 21, and 32, T. 63 N., R., 17 W., and along the shore for one half mile westward.

It is evident that the Stuntz conglomerate on the south shore of Vermilion Lake is a true water-deposited conglomerate, of the same formation as the slates and graywackes of the district, the conglomerate grading into the quartzite and graywacke, and this into argillaceous slate. Furthermore, as supposed by Van Hise, the conglomerate lies unconformably on the iron-bearing formation, and contains very numerous fragments of jaspilite. The position of this unconformity, whether at the base of the Taconic or lower is not ascertained.

The nature and position of the conglomerate in the valley of the Puckwunge, a small stream entering the Pigeon River north of Grand Portage, is discussed. This conglomerate is overlain by igneous rocks, resembling the traps of the Keweenawan. The subjacent formation cannot be certainly determined, but in the same locality, at a lower level, is a slate rock, called the Puckwunge slate, which was followed for some distance north and east, and which is probably an upper member of the Animikie, not before individualized. The conglomerate contains quartzite pebbles, which are referable to the quartzites of the Animikie, farther north. It may be inferred that this is the basal conglomerate of the Keweenawan, which has been identified up to Grand Portage island, and at intervals along the Lake Superior coast, from Baptism River to near Beaver Bay.

Winchell[1] discusses some resemblances between the Archean of Minnesota and of Finland. The succession in northeastern Minnesota, as made out largely from field work done in 1897, is as follows, in descending order.

1. *Granitic intrusion*, cutting and metamorphosing the earlier schists and fragmentals. This rock is seen about Snowbank Lake and Moose Lake, about the western confine of Disappointment Lake, and at Kekequabic lake.

2. *Upper Keewatin.*—This consists of conglomerates (at Stuntz Island and at Saganaga and Ogishkie Muncie lakes), sericitic schists, quartzose and micaceous schists, graywackes, clay-slates, chloritic schists, and porphyroids. The mica-schists, embracing many conspicuous bowlder-

[1] Some resemblances between the Archean of Minnesota and of Finland, by N. H. WINCHELL: Am Geol., Vol. XXI, 1898, pp. 222–229.

like forms on the weathered surfaces, are to be seen about Moose Lake, and southeast to Snowbank Lake, about Disappointment Lake, Kekequabic Lake, and eastward to Zeta Lake.

3. *Granitic intrusion*, chiefly represented by the granite of Saganaga Lake, where the Upper Keewatin lies unconformably upon it. It is also seen a little west of Ely and on the Kawishiwi River. At West Seagull Lake this granite cuts older greenstones and green schists.

4. *Lower Keewatin or Kawishiwin.*—This is mainly a greenstone formation, both massive and fragmental, and constitutes the oldest formation in the state. When stratified it consists of basic tuffs, agglomerates, and green stratified schists and greenwackes. It contains the banded jaspylites and iron ores at Vermilion Lake. Where cut by granite and porphyry (1), these rocks are converted to mica-schist and banded gneiss.

Unconformably above all these is the Animikie formation, of Taconic age, the base of the Paleozoic.

Nos. (1), (2) and (3), above, are paralleled in Finland by similar rocks in similar order, as described by Sederholm. Rocks corresponding to No. (4), the Lower Keewatin, seem to be wanting, or are seen only as inclusions in the next younger granite.

It is probable that the divisions above detailed for Minnesota and Finland are wholly embraced in the lower division of the Canadian Laurentian, *i. e.*, in the Ottawa gneiss, and that they have not yet been noted in Canada. The fundamental gneiss of Canada is, therefore, not the bottom of the geological series, but is largely a sedimentary series, derived from an older series, this older series being in part at least a greenstone, as indicated by the stratigraphic succession in Minnesota.

Comments.—In the above papers Winchell has modified his ideas from time to time with reference to the general succession of the pre-Cambrian rocks of northeastern Minnesota, and it may be well briefly to summarize what appear to be his latest conclusions. The succession from the base upward is as follows: (1) greenstone, both massive and fragmental, called the Lower Keewatin; (2) cutting this is a massive granite, typically developed at Saganaga Lake; (3) unconformably above the Lower Keewatin is a series of sedimentary rocks, consisting of conglomerates, sericite-schists, quartzose and micaceous schists, graywackes, clay-slates, chloritic schists, and porphyroids, called the Upper Keewatin; (4) granite cutting and metamorphosing all the preceding.

The correlation of the Minnesota series with the Ottawa gneiss and with the Finland series must be considered a pure conjecture. The Minnesota succession is not agreed upon; these widely separated regions have not been connected by structural work, and of course in the case of Finland never can be; and lastly, fossil evidence is lacking. Any correlation of the ancient crystalline rocks without the basis of connecting structural work or fossil evidence, must be considered as little more than a guess, having no foundation in inductive knowledge.

The massive igneous rocks of the Laurentian, mostly granites, which intrude the sedimentary rocks, are believed by Winchell to be due to the aqueo-igneous fusion of the lower portion of the sedimentary rocks, and the intrusion of the magma thus formed into the overlying sediments. The argument adduced in favor of this origin is based almost entirely upon an occurrence cited at Kekequabic Lake of a transition from igneous rocks to the clastic rocks there found. In 1891 and 1892 Grant[1] studied this area, and found no evidence of a transition from the semicrystalline and crystalline schists into granite. On the contrary, abundant evidence was found of the eruptive nature of the granitic rocks in the surrounding sedimentaries. The same area was closely studied by a party of the U. S. Geol. Survey during 1898, and the same conclusion was reached. The principal support of Winchell's theory is thus taken away, and it stands as an unproved hypothesis.

Grant[2] describes and maps the geology of Kekequabic Lake in northeastern Minnesota. By far the larger proportion of the rocks represented are clastics, which are divided for convenience into four groups. The first and most extensive group is the slate formation, consisting largely of argillites, with smaller amounts of fine and coarse graywackes and grits, the coarser phases becoming distinctly conglomeratic in places. The second group consists of coarse conglomeratic rocks, which are a part of the Ogishke conglomerate. The third group is made up of certain fissile green schists, which are believed to be water deposited, and probably originally formed from fine volcanic ash. The fourth

[1] Twentieth Ann. Rept. Geol. and Nat. Hist. Surv. of Minn., 1893, pp. 69–82; and Twenty-first Ann. Rept., *ibid.*, pp. 50–54.

[2] The geology of Kekequabic Lake in northeastern Minnesota, with special reference to an augite soda granite, by U. S. Grant: A thesis accepted for the degree of Ph.D in The Johns Hopkins University, 1893. Published in Twenty-first Ann. Rept. Geol. and Nat. Hist. Surv. of Minn., for 1892, pp. 5–58, 1893. With geol. map and plates.

group consists of volcanic fragmental material, in part deposited in water. All of these clastic rocks now stand in nearly vertical positions, with a strike a little north of east.

Sharply marked off from the clastic rocks are four types of igneous rocks, hornblende-porphyrite, granite, diabase, and gabbro. The granite is divisible into two types, ordinary granite, and granite-porphyry, in both of which the ferro-magnesian constituent is almost exclusively pyroxene and the predominating feldspar anorthoclase. The origin of the granite is truly eruptive; having broken through the surrounding clastics; the rock is not formed, as held by N. H. and A. Winchell, from the recrystallization in situ of the sedimentaries of the region.

The slate formation, the green schist, and the volcanic tuff belong to the Keewatin, the Minnesota equivalent of the Lower Huronian. The conglomerate contains pebbles, many of which are similar to some of the Keewatin rocks, and it seems to belong to a newer series, although as yet no unconformity between the conglomerate and other rocks has been discovered. Following Lawson, it is believed that the conglomerate is a part of the Keewatin, probably separated from the lower part of that series by an unconformity, and that it is much older than the Animikie. However, the question whether the clastics belong to one or two series is as yet open.

The porphyrite and the granite are of Keewatin age. The porphyrite is regarded as contemporaneous with the deposition of volcanic tuff and green schist, and the granite is believed to date from the folding of the Keewatin. The age of the diabase dikes is not known; they are perhaps contemporaneous with the great diabase intrusions in the Animikie. The gabbro is of early Keweenawan age.

Grant[1] sketches the geology of the eastern end of the Mesabi iron range in Minnesota, including T. 64 N., Rs. 3 and 4 W., and parts of Rs. 2 and 5 W., with some adjacent portions of Ontario. The rocks can be separated into three divisions. The chief one of these is the Animikie series, containing the iron-bearing rocks of the Mesabi range. Older than the Animikie is a series of granites, greenstones both massive and schistose, conglomerates, slates, and other clastic rocks, called the pre-Animikie. Younger than the Animikie are some diabase sills and the great gabbro mass of northeastern Minnesota.

[1] Sketch of the geology of the eastern end of the Mesabi iron range in Minnesota, by U. S. GRANT: Engineers' Year Book, Univ. of Minn., 1898, pp. 49–62. With sketch map.

Of the pre-Animikie rocks, the greenstones and clastic rocks have been called Keewatin. As the greenstones are usually associated with the Mesabi iron-bearing rocks, these alone of the Keewatin rocks are described. They lie to the north of the iron-bearing rocks in T. 65 N., R. 5 W., and extend eastward to the center of T. 65 N., R. 4 W., where they disappear under the Animikie strata. In general, the greenstones are at present diorites; originally some were certainly diabases, others were of the nature of andesites, and a large part were diorites, or possibly gabbros. At places, especially along the east side of Sec. 27, T. 65 N., R. 5 W., the greenstones contain angular and subangular fragments of rock almost like themselves, and some may be regarded as composed of fragmental volcanic rocks. Associated with the greenstones, especially in Secs. 22, 23, and 24, T. 65 N., R. 5 W., are small masses of more acid rocks, quartz porphyries and quartzless porphyries, which are probably younger than the greenstones.

The pre-Animikie granite has its typical development on the shores of Saganaga Lake. In a number of places it may be seen in intrusive relations with the greenstone. A quarter of a mile south of the N. E. corner of Sec. 23, T. 65 N., R. 5 W., many granite dikes cutting the greenstone are seen, and on the south shore of West Seagull Lake granite dikes of the same nature as the immediately adjacent main mass of Saganaga granite are seen cutting the greenstone. Both granite and greenstone are cut by another series of finer grained, more acid granite dikes.

The Animikie rocks rest unconformably upon the pre-Animikie rocks, and usually on the southern slope of the Giant's Range, which is composed essentially of granite. The strike is approximately E. N. E., and the dip in general about 10° E. of S. The thickness varies from nothing to 4000 feet. The Animikie is separable into four conformable divisions: (1) the lower or quartzite member, called the Pewabic quartzite; (2) the iron-bearing or taconyte member; (3) the black slate member; (4) the graywacke-slate member.

(1) The quartzite member is well developed in Itasca county, but disappears before reaching the eastern side of St. Louis county.

(2) The rocks of the iron-bearing member are similar to those in St. Louis county on the western end of the range, described by Spurr.[1] They differ, however, in two features. They are more completely

[1] Geol. and Nat. Hist. Surv. of Minn., Bull. X, 1894.

crystalline, and the iron is magnetite instead of hematite. The rocks consist chiefly of jaspers, amphibole (grünerite) schists, greenish siliceous slates, cherts, cherty carbonates, and magnetite slates. It is believed that these rocks were originally glauconitic green-sands; that the ore has been derived from the iron in the glauconite, and that the ore bodies result from concentration and replacement. In this part of the Mesabi range no ore bodies have yet been found which are at the same time both rich enough and large enough for profitable mining, although vast quantities of magnetite ore occur at or near the surface.

The dip of this formation varies from an average of 45° to 50° on the west to less than 15° on the east, and the thickness varies from 650 feet or less on the west to 900 feet on the east.

(3) The black slate is essentially a fine-grained, black, more or less siliceous, apparently carbonaceous slate.

(4) The graywacke-slate member is composed of black to gray slates and fine graywackes, with some flinty slates; the upper part shows coarser detrital material, and the highest beds seen are fine-grained quartzites and quartz-slates. This member is well exposed on the south shore of Loon Lake.

Associated with all of the strata of the Animikie are diabase sills, and bounding the Animikie rocks on the south is the great gabbro mass. These are igneous rocks of later date than the Animikie. Near the contact with the gabbro the Animikie rocks show marked metamorphism, and usually complete recrystallization. The gabbro varies from a nearly pure plagioclase rock to titaniferous magnetite.

The pre-Animikie rocks here described, according to the nomenclature used by the United States Geological Survey, belong to the Lower Huronian series of the Algonkian system, and probably also in part to the older Archean or Basement Complex; the Animikie is regarded as the equivalent of the Upper Huronian series of the Algonkian, and the gabbro as the lower part of the Keweenawan series of the Algonkian.

Winchell, Alexander,[1] gives a detailed petrographical description of the Koochiching granite occurring on the north boundary of Minnesota, about two miles west of Rainy Lake. The rock is a biotite-hornblende granite of eruptive origin, and is assigned to the Laurentian.

[1] The Koochiching Granite, by ALEXANDER WINCHELL: Am. Geol., Vol. XX, 1897, pp. 293–299.

Coleman makes notes on the petrology of Ontario, including the Port Coldwell, Missanabie, and Wahnapitae areas.[1]

Coleman makes a third report on the gold region of western Ontario.[2]

The districts visited and here reported upon are the Upper Seine district, the Shoal Lake district, the Manitou district, the country crossed between Manitou Lake and the Lake of the Woods, the Lake of the Woods district, the West Shoal Lake district, the neighborhood of Rat Portage, and the vicinity of Fort William on Lake Superior. As in previous reports, the general geology worked out by Lawson for the Lake of the Woods and Rainy Lake districts is accepted, and the general principles applied to other districts of the region visited.

In previous years it has been held that gold was to be looked for only in the Huronian. During the past three years, however, it has been found that some of the most promising gold deposits occur in the granite or gneiss. It has also been found that the best veins, or other ore deposits, occur at or near the contact of the Laurentian eruptive rocks and the Huronian.

In the Ontario region the gold deposits occur in the following ways. (1) True fissure veins, commonly found in the areas of massive eruptive granite. (2) Lenticular or bedded veins, confined to the schistose rocks. These are intercalated between the schists and run parallel with their strike, and are not so continuous as the fissure veins. (3) Contact deposits, between the Huronian and Laurentian. These are rare in this district. (4) Fahlbands of schists, impregnated with pyrites and other sulphides. (5) In quartz, associated with dikes of porphyry or felsite, near the contact of the Huronian and Laurentian rocks, penetrating the schists, and sometimes the granite itself. (6) In an eruptive mass, in but one locality. (7) Placer deposits.

Coleman[3] gives an interesting general account of the clastic Huronian rocks of Western Ontario, in the region extending from the Lake of the Woods in the west to Lac des Mille Lacs on the east, a

[1] Notes on the petrology of Ontario, by A. P. COLEMAN: Rept. Bureau of Mines, Ontario, Vol. VI, 1898, pp. 145–150.

[2] Third report on the west Ontario gold region, by A. P. COLEMAN: Rept. Bureau of Mines, Ontario, Vol. VI, 1897, pp. 71–124.

[3] Clastic Huronian rocks of Western Ontario, by A. P. COLEMAN: Rept. Bureau of Mines, Ontario, Vol. VII, 1898, pp. 151–160. Published also in Bull. G. S. A. Vol. IX, 1898, pp. 223–238.

distance of 200 miles, with a width north of Rainy Lake of 120 miles. The Huronian, including the Keewatin and Couchiching rocks, is in general an immense series of water-worn sediments, in the upper part mixed with eruptives, perhaps largely later injections, but partly pyroclastic. The Keewatin is largely of eruptive origin, though it contains important sedimentary members; the Couchiching is entirely sedimentary.

The Keewatin, and in the southern part of the region the underlying Couchiching, form sharp synclines, curving as wide meshes around the areas of Laurentian, which vary from less than a mile to fifty miles in diameter.

Diabase and porphyry eruptives form an important part of the Keewatin. These are in large part surface flows, represented by ash rocks, agglomerates, etc., but many of them are probably laccolitic sills. The water-formed clastics of the Keewatin, include limestones, slates, quartzites, grits, graywackes, breccias, and pebble and bowlder conglomerates. The limestones are of limited extent, being found in any thickness only at Steep Rock Lake. The slate on analysis yields 7.44 per cent. of carbon, pointing perhaps to the presence of life. The conglomerates are in places schistose. Near Shoal Lake the most common pebbles are quartz-porphyry and porphyrite, felsite, and green schists indistinguishable from the adjoining Keewatin schists; black and red quartzite, white pulverulent sandstone, vein quartz, and anorthosite. No gneiss or granite pebbles have been found. Most of these pebbles are easily matched by Keewatin rocks, sometimes, however, many miles distant; a few are evidently Couchiching; and none are Laurentian.

The break represented by this conglomerate comes high up in the Keewatin, instead of at its base, just above the Couchiching, as held by Lawson. Striking evidence that the break is not at the base of the Keewatin is found at Shoal Lake, where a few bowlders of the coarse-grained anorthosite found in the schist-conglomerate are exactly like portions of a boss of anorthosite two miles away. As this anorthosite area contains masses and strips of characteristic Keewatin schist, swept off during its eruption, it is evident that an immense lapse of time separates the conglomerate and the underlying Keewatin. It is probable that the conglomerates represent an important interval of erosion, perhaps equivalent to the one shown by Van Hise and others between the Upper and Lower Huronian in the states to the south.

The Couchiching rocks are all formed of clay sand, more or less metamorphosed; in general they are biotite-schists or gneisses, the quartz showing a clastic origin. The Couchiching passes up by transition into the Keewatin, and there is no reason why the two together should not be classed as Huronian.

Following Lawson's estimate, the Keewatin and Couchiching series together sum up 50,000 feet in thickness.

The term Laurentian is employed, as Lawson and other Canadian geologists are accustomed to employ it—in a petrographical and structural sense—for crystalline gneisses and granites underlying the Huronian, although it is evident that these rocks have consolidated at a time later than the Huronian.

As described by Lawson, the Laurentian (Lower Archean) "occurs in large isolated central areas, more or less completely surrounded by the schists of the upper Archean, the encircling belts anastomosing and forming a continuous mesh work." It consists chiefly of a coarse reddish, often porphyritic rock, usually granite in the central part of the area, but showing a foliation, generally parallel to the periphery, where it comes in contact with the Huronian.

Throughout the region the Laurentian is in eruptive contact with the Huronian, and nowhere is a basal conglomerate of the Huronian found. Near the contact with the Huronian, strips and fragments of the Huronian are embedded in the gneiss; also dikes of granite, pegmatite or felsite generally run from the gneiss into the Huronian. The larger areas of gneiss and granite are evidently batholites. Some of the smaller granite bosses may be stumps of old volcanoes. The Huronian schists usually dip rather steeply away from the gneiss, at an angle seldom less than 45°. Finer-grained granites cut both the Keewatin and the Laurentian. However, it is not easy to say whether a given granite is Laurentian or a later granite.

It is believed that as a result of the piling up of a thickness of eight or ten miles of sediments and eruptive materials, represented by the Keewatin and Couchiching rocks, the slowly rising isogeotherms softened or fused the foundation, which rose into domes, the inner parts solidifying as granite, and the outer, more viscid portions having their constituents dragged into rough parallelism with the adjoining solid rocks and forming gneiss.

As the Huronian rocks south of Lake Superior and in New Brunswick are described by Van Hise and Dawson as presenting basal con-

glomerates resting unconformably on the Laurentian, it is suggested that in these cases the thickness of the sediments was not great enough to depress the Laurentian floor to the level of fusion or plasticity; or, that the Huronian, as recognized in these regions, is really younger and overlies the upturned edges of the rocks described as Huronian in the northern Archean.

Comments.— The above discussion is based on the most thorough field work yet done in this area, and the account probably marks an advance in the interpretation of the pre-Cambrian stratigraphy of the area northwest of Lake Superior, although the conclusions cannot yet be accepted as final. Some of the conclusions differ from those of other workers in this area, and such may be especially noted.

The Couchiching is believed to be entirely a sedimentary series, conformably below the Keewatin, and in eruptive contact with the Laurentian granite and gneiss below. Lawson regarded the Couchiching as sedimentary, but believed that there was an unconformity between it and the Keewatin, because of the great differences in the characters of the materials, the degree of crystallization, and the presence of basal conglomerates in places at the base of the Keewatin. Coleman has previously accepted these conclusions. Van Hise, accepting Lawson's conclusion as to the position of the Couchiching below the Keewatin, supposed the Couchiching to belong to the Basement Complex or Archean. However, recent personal work in the field has led him to the conclusion that the Couchiching of Rainy Lake is largely a sedimentary series, which is equivalent in age to the upper part of the series mapped by Lawson as Keewatin in the same area.

The insistence on the eruptive contact of all the rocks of the Laurentian with the Huronian and the explanation of the origin of the Laurentian may also be noted. Coleman believes that the gneisses and granites of the Fundamental Complex do not represent the earth's *erstarrungskruste*, but are portions of the earth's crust, of sedimentary or other origin, which have been buried deeply enough for hydrothermal fusion, and have afterwards been disinterred by long-continued denudation. After fusion of course such rocks would be really eruptive and of later age than the Huronian rocks above, even though originally they may have been older than them and formed the floor upon which the Huronian rocks were deposited. This is essentially the position of Lawson. Van Hise, on the other hand, believes that here the granites and gneisses heretofore included under the Laurentian of this

region may be separated into (1) a granite-gneiss basal complex, forming the basement upon which the Huronian was deposited, and perhaps representing a portion of the original crust of the earth or its downward continuation, and (2) later granite and gneiss intrusive in the Huronian, and therefore of Huronian or post-Huronian age. This discrimination has been uniformly made south of Lake Superior, in a number of cases in Canada, and in other parts of North America, and it is believed that it may also be made in this region of western Ontario. If this were done the rocks of the true fundamental complex in this area would occupy perhaps a very small area. Whether such a complex may be called Archean, as advocated by the United States geologists, or by some other name, is immaterial. If the term Laurentian be employed, it would need to be redefined to cover the narrower range of rocks, and because of its present wide application, including both the basal complex and later eruptives, some confusion might result. The term Archean has been carefully defined and consistently used by the United States geologists to represent the oldest group of rocks or basal complex, and in this narrow application has priority to any other term.

The portion of the granites and gneiss intrusive in the Huronian would be called simply Huronian or post-Huronian. If the true basal complex be altogether absent in this region, the granites and gneisses now called Laurentian are of Huronian or post-Huronian age, and are not to be correlated with rocks of the true basal complex of other areas.

Parks [1] describes the geology of the base and meridian lines in the Rainy River district, in an area extending from Lac Seul on the northwest and Lake Wabigoon on the southwest, to Sturgeon Lake and Mattawa Lake on the east. Laurentian and Huronian rocks occur in folds with a general northeast-southwest trend. The Huronian rocks occur in three main areas, the Sturgeon River area, the Lake Minnetakie area, and the Wabigoon Lake area. They consist of altered traps, hornblende-schists and other green schists, altered porphyrites, quartz porphyries, phyllites, and conglomerates. In general they resemble Lawson's Keewatin series to the south. The Laurentian consists of hornblende-syenite, hornblende-granite-gneiss, mica-syenite, biotite-granite-gneiss, and various granitic rocks. C. K. LEITH.

[1] Geology of base and meridian lines in the Rainy River district, by W. A. PARKS: Rept. Bureau of Mines, Ontario, Vol. VII, 1898, pp. 161–183. With geological map.

Reviews

Report on the Building and Decorative Stones of Maryland. By George P. Merrill and Edward B. Mathews. Part II, Vol. II, Geol. Survey of Maryland.

The first 75 pages of the Building Stone Report of the Maryland Geological Survey are written by George P. Merrill, and comprise a discussion of the physical, chemical, and economic properties of building stones. The following 116 pages are written by Edward B. Mathews, and are an account of the character and distribution of Maryland building stone.

In the first part Merrill classifies the rocks of Maryland, which are available for constructive and ornamental purposes, into (1) granites and gneisses; (2) common limestones and dolomites; (3) the marbles (crystalline limestones and dolomites); (4) sandstones and conglomerates; and (5) the argyllites and slates. The three great classes of rocks, eruptive, clastic sedimentary, and metamorphic; the diversity of the geological resources of Maryland; the method of formation, present position, and the conditions under which the sedimentary and igneous rocks formed; and the way in which mountain-building forces have since modified them, are successively discussed.

The author explains how several grades, and often kinds, of sedimentary rocks may occur in a single quarry. The effect which the position of the strata, horizontal or tilted, has upon the cost of quarrying; the size and shape of the blocks resulting from jointing and bedding; the manner in which river erosion, weathering, and glaciers influence the accessibility of the stone in the quarry; and the misleading nature of dry seams and superficial induration, are clearly explained.

Following a discussion of the general distribution of Maryland building stones in reference to the physiographic regions of the state, Merrill considers the methods of quarrying and the more important kinds of machinery now employed. The important part which competition plays in the development of the stone industry has led to a

brief discussion of the quarrying industry of each of the Atlantic coast states. In this the author briefly describes the kinds of rocks quarried and reviews the character of the output and the facilities for successful development. It is concluded from these observations that the future of the quarrying industry of Maryland must depend not so much upon the kinds of materials as upon the ability to compete in prices.

After treating the subject of weathering in general, Merrill refers more particularly to the effects of alternating temperatures and the freezing of included water. The danger of laying stone on edge, on account of the freezing of water which may collect along the sedimentary planes, as well as the results of water freezing in the pores of the rock, are emphasized. In this connection the author concludes that "other things being equal, a stone possessing low absorptive power will be more durable . . . . than one that will absorb a large amount;" "granites and gneisses, possessing low ratios of absorption, and being made up so largely of silica and silicate minerals, are very little affected by freezing and solution;" and that "a ratio of absorption of more than 4 per cent. by weight (in sandstones) must be regarded as unfavorable."

In a discussion of the physical tests Merrill describes in an interesting manner the more important methods employed by different experimenters in performing the various durability and strength tests. In the discussion of the freezing and thawing tests the observation is made that "the results obtained on coarse and fine varieties of Portland sandstone suggest at least that water would freeze out of coarse stone, and therefore create less havoc than in those of finer grain." In the discussion of the specific gravity the conclusion is reached that "of two stones having the same mineral nature, the one having the highest specific gravity, that is, the greatest weight bulk for bulk, will be the least absorptive, and hence, as a rule, the most durable." The method suggested for determining the weight per cubic foot of stone is to multiply the weight of a cubic foot of water by the specific gravity of the stone. The method suggested for obtaining the absorptiveness of the rock is the one commonly employed, of soaking the sample in water for three or four days and determining the percentage gained in weight thereby.

In speaking of the crushing strength of stones, the author believes that to continue making these tests is unnecessary, except in "extreme cases."

Since the first of the century the quarrying industry of Maryland has received attention incidentally from many different students of geology. The various publications which have resulted from these studies are summarized by Mathews in the first pages of the second part of the report. Mathews considers the more important quarry areas under the heads of (1) granite and gneiss; (2) marbles, serpentines, and limestones; (3) quartzite and sandstones; and (4) slates and flags. This classification is somewhat different from that followed by Merrill in the first part of the report.

In the treatment of each area the author gives a brief historical sketch of the development of the industry, and a discussion of the rocks as they occur in the quarry. In some instances the microscopical and chemical analyses are given, and also the results of physical tests, including a determination of the crushing strength, ratio of absorption, specific gravity, and weight per cubic foot. The rock as it occurs in the quarries and natural exposures; the mineralogical composition and texture; and the colors of the granite, limestone, marble, serpentine, and sandstone, are well illustrated by cuts, photomicrographs, and colored lithographic plates.

The granites of Maryland are shown to be ordinarily schistose, and mainly of a gray color. The granite from one or two of the quarries is described as having a reddish or pinkish color, but possessing a porphyritic texture. In the case of the rock known as gneiss, occurring in the vicinity of Baltimore, the color and texture vary with the alternation of layers. In all cases the dimensions are controlled by jointing planes, which strike in various directions, owing to which the stone can often be used only for the smaller constructional purposes.

The marbles and limestones of Maryland are the most widely distributed of all the building stones, and occur in most of the formations from the Algonkian to the Triassic. The Cockeysville marble is exploited the most largely, and is probably the best known of Maryland limestones or marbles. The Potomac marble is a conglomerate with a striking color and texture, and is the only stone of this character used to any extent in the United States.

Serpentine has been quarried in several places, mainly for decorative purposes. Dry seams have seriously interfered with the successful development of this stone, and the quarries have been temporarily abandoned.

Sandstone is quarried extensively in only one locality, Seneca. The

best stone in the quarries is interstratified with beds of unsalable material, which naturally interfere with the economy of working.

Slate has been quarried in two different areas in Maryland, known as the Peach Bottom district and Ijamsville. The former district is the only one in which quarrying is now actively carried on. From this district a good quality of slate is obtained. The output has shown a slight decrease since 1894, when it reached its maximum importance.

E. R. Buckley.

Fifteenth Annual Report of the State Geologist (*New York*) *for the Year 1895*, Vol. I. James Hall, State Geologist, Albany, 1898.

This report, published in a ponderous volume of 738 pages with broad margins, large type and heavy paper, is particularly unwieldy, and would be far more convenient for the student were it issued in a size and form conformable with the preceding reports of the survey. It is particularly aggravating to the librarian to have a continuous series of reports which should be kept together upon his shelves vary so greatly in size. The 1894 report and those preceding it are convenient sized octavo volumes, while this 1895 report is a great book standing fourteen inches high, although the matter contained, page for page, is about equivalent to that in the earlier reports. The edition of the report, issued as a part of the regents' report of the New York State Museum, is printed upon thinner paper, and has the margins trimmed down so that it is a more convenient size, but even that is considerably larger than the preceding reports of the survey.

The criticism upon the style of publication, however, cannot be extended to the contents of the volume as each one of the papers communicated is a valuable addition to the literature of New York geology, and many of them are of more than local interest. Each of the papers will be briefly noticed, much of what follows being taken from the "Synopsis of Results" by the state geologist upon pages 11–26 of the report.

Two paleontologic papers, both by James Hall, (1) "A Discussion of Streptelasma and Allied Genera of Rugosa Corals," and (2) "The Paleozoic Hexactinellid Sponges Constituting the Family Dictyospongidæ," are announced in the synopsis of the report but do not appear. However, since this volume is marked Volume I on the title-

page, it is possible that another part containing these papers is contemplated.

1. *The Stratigraphic and Faunal Relations of the Oneonta Sandstones and Shales, the Ithaca and Portage Groups in Central New York.* By J. M. CLARKE. Pp. 27–81, plates I–VII and two maps. "This report presents a revision and summary of observations previously made by the same author with reference to the position of the Oneonta sandstones and their extent westward from the Chenango River, and adds thereto more recent data bearing upon the passage of the Ithaca fauna in the region of its highest development in Cortland and western Chenango counties into the typical fauna of the Portage group."

"The *Portage group* is a series of arenaceous deposits representing the geological time which elapsed from the close of the Hamilton period (including the Tully limestone and a portion of the Genesee slate when present) to the opening of the Chemung period. The typical and unmixed fauna of its westerly sections has little organic relation to the proper fauna of the Hamilton shales, the Chemung fauna succeeding, or the Ithaca faunas adjoining on the east. It is an exotic fauna, evidently derived from the west and making its first appearance in the Genundewah limestone of the Genesee slates. It is the *Naples fauna.*"

"The fauna of the central and east-central sections is an indigenous fauna, and its organic composition stands in the closest relation to the fauna of the Hamilton group, but in its later manifestations assumes many characters of the Chemung fauna. In the Chenango Valley and eastward the upper portion of the deposits of this age is represented by the Oneonta group with a very sparse fauna and well-characterized strata. In Chenango county they replace the higher beds bearing the Ithaca fauna."

2. *The Classification and Distribution of the Hamilton and Chemung Series of Central and Eastern New York.* By C. S. PROSSER. Pp. 83–222, plates I–XIII and one map. The investigations described in this report were undertaken in order to trace the boundaries of the Oneonta group of sandstones and shales and to elucidate as far as possible the division line between the Hamilton group and the overlying strata. This latter is a perplexing problem because east of the Chenango River the Tully limestone and Genesee slate are wanting and the sandy shales of the Hamilton group pass upward into those of the Ithaca group with slight lithologic changes and with alterations of

the fauna so gradual as to be perceptible only upon very careful observation. It is shown that the more or less barren Sherburne sandstones separate the faunas of the Hamilton and Ithaca groups, and represents the beds which have been designated as Lower Portage in western New York. The correctness of this correlation is shown by the discovery of the typical Tully limestone species *Hypothyris venustula* = *H. cuboides* just below the Sherburne sandstone near Noblesville in Otsego county very much farther east than this species has been previously found.

The results of Prosser's investigation necessitate the changing of the upper boundary of the Hamilton formations from five to fifteen miles further south than the similar line on the geologic map recently published by the Geological Survey of New York.

3. *The Stratigraphic Position of the Portage Sandstones in the Naples Valley and the Adjoining Region.* By D. D. LUTHER. Pp. 223–236, plates I–II and one map. The purpose of the investigation described in this paper was to ascertain the dividing line between the Portage and the overlying Chemung group in western New York. The section of the Portage series in the Naples Valley is described in detail, and the Portage sandstone which marks the upper limits of the series is shown to lie at an elevation of 600 feet above the base of the series. With the data derived from the study of the Naples section the Portage sandstone is traced eastward to Seneca Lake and westward to Lake Erie.

4. *The Economic Geology of Onondaga County, New York.* By D. D. LUTHER. Pp. 237–303, plates I–XXI and one map. In this paper the rock formations of the county, from the Clinton group below to the Portage shales above, are discussed in their proper order of succession. While attention is given to the geologic character and distribution of each formation, the especial value of the report consists in its exhaustive treatment of the most important economic products of the county, viz., salt, soda-ash, gypsum, hydraulic cement and quarry stone.

5. *The Structural and Economic Geology of Erie County.* By I. P. BISHOP. Pp. 305–392, plates I–XVI, figures 1–6. This paper opens with a brief account of the topography of the region, after which the stratigraphic succession is discussed at considerable length. The formations present extend from the Salina group at the bottom to the Portage group at the top. The superficial deposits are discussed under

the head, "Quaternary Geology." The economic products of the county which are discussed are building stone, hydraulic cement rock, clays, sand, gravel and natural gas. In connection with the discussion of these products many valuable statistics are given and a considerable amount of space is devoted to the records of wells which have been sunk for natural gas in and about Buffalo.

6. *Geology of Orange County*. By H. RIES. Pp. 393–475, plates I–XLII, with one geological map. In this report the physiography and topography and the stratigraphic, structural and economic geology are ably discussed in detail. The formations present extend from the pre-Cambrian gneiss at the base of the section to the Chemung group at the summit. The economic products described are road materials, brick clays, limestone, lead ore, building stone, flagstone, and iron ores, besides the soils, mineral springs, water power and water supply.

7. *Report on the Crystalline Rocks of St. Lawrence County*. By C. H. SMYTH, JR. Pp. 477–497. The principal purpose of the investigation described in this paper was to determine the distribution of the crystalline limestones, and to collect data bearing upon the question of the origin of the gneisses and the relation existing between these rocks and the limestones.

8. *Report on the Geology of Clinton County*. By H. P. CUSHING. Pp. 499–573, plates I–V. This paper discusses the topography and general geology of the region, after which each township is treated separately. The rock series discussed are, (1) gneissic series; (2) limestone series; (3) gabbro series; (4) Paleozoic series, extending from the Potsdam sandstone to the Utica slate; (5) dike series; (6) pleistocene deposits.

9. *Preliminary Report on the Geology of Essex County*. By J. F. KEMP. Pp. 575–614, plates I–XII. This is a continuation of the report by the same author in the 1893 report, and the townships not previously described are taken up for special consideration and the areal geology of each is described so far as it has been determined. Special notice is taken of economic products, namely, of iron ores.

10. *Sections and Thickness of the Lower Silurian Formations on West Canada Creek and in the Mohawk Valley*. By C. S. PROSSER and E. R. CUMMINGS. Pp. 615–659, plates I–XII. The writers here consider the Ordovician rock sections exposed in the gorge of the West Canada Creek at Trenton Falls, at Newport and at Little Falls. These

sections have all been previously studied by other observers, some of them frequently, and not always with concordant results. In this paper, both measurements of thickness, and identification of species of fossils have been made with care, and while the conclusions are not in complete harmony with already expressed opinions, they doubtless afford a more precise knowledge of the formations considered.

11. *Report on the Talc Industry of St. Lawrence County.* By C. H. SMYTH, JR. Pp. 661–671.

12. *Physical Tests of the Devonian Shales of New York State to Determine their Value for the Manufacture of Clay Products.* By H. REIS. Pp. 673–698. This paper is introduced by a brief discussion of the general, chemical and physical properties of shales. This is followed by some notes upon the manufacture of paving brick and the requisite qualities of such brick. The remaining pages are devoted to a discussion of the extent of the New York shales with tests of samples from typical localities.

13. *The Discovery of Sessila Conularia.* By R. RUEDEMANN. Pp. 699–728, plates I–IV. This important paper is based upon the study of some obscure organisms found in the Utica slate at Dolgeville, N. Y. As a result of the study much light is thrown upon the nature and mode of development of this widespread but little understood organism, *Conularia*, in regard to whose taxonomic position there has been a widely diverse expression of opinion. *Conularia* has usually been referred to the Pteropods, but the results of the investigation recorded in this paper seem to indicate that it should be placed with the Cephalopods.

14. *Notes on Some Crustaceans from the Chemung Group of New York.* By J. M. CLARKE. Pp. 731–738. In this paper are discussed two crustaceans from the Chemung group, (1) *Pephricaris horripilata*, a peculiar, highly ornamented Phyllocarid crustacean, and (2) *Bronteus senescens*, one of the very few trilobites of this formation.

STUART WELLER.

Iron Making in Alabama. By W. B. PHILLIPS. Alabama Geol. Surv., Second Ed., 380 pp. 1898.

It is not often that a state survey finds it necessary to issue a second edition of any of its reports, and the fact that Dr. Phillip's well-known report now appears in new form is a well deserved compliment

to both the author and the enterprising Survey of Alabama. It is more than that; it is a very notable indication of the rapid progress which Alabama is making in iron making. An examination of the report shows this progress strikingly. Over a hundred pages of new matter have been added and chapters on Coal and Coal Washing, Concentration of Low-Grade Ores and Basic Steel and Basic Iron, indicate the lines of progress. The first edition of the report was intended for a general treatment from the point of view of raw materials. The new edition, by the addition of much valuable matter, has become as well almost a manual on iron making from low grade ores and is accordingly of much wider usefulness. In bringing together widely separated technical papers and adding to the material so much from the results of his own laboratory, Dr. Phillips has placed all interested in the subject in his debt. It is unfortunate that so good a report should be presented in such poor form. The paper, press work, and proof reading leave much to be desired. H. Foster Bain.

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—Bulletin of the American Museum of Natural History, Vol. X, 1898. New York, N. Y.

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— RUSSELL, I. C., PROFESSOR. Glaciers of Mount Ranier. Extract from the Eighteenth Annual Report of the U. S. Geological Survey, 1896–7. Part II. Papers Chiefly of a Theoretic Nature. Washington, 1898.

— SARDESON, F. W. What is the Loess? American Journal of Science, Vol. VII, 1899.

— SMITH, WILLIAM SIDNEY TANGIER. A Geological Sketch of San Clemente Island. From the Eighteenth Annual Report of the U. S. Geological Survey, 1896–7. Part II. Washington, 1898.

— TODD, JAMES E., State Geologist. South Dakota Geological Survey, Bulletin No. 2. First and Second Biennial Reports on the Geology of South Dakota, with Accompanying Papers, 1895–6.

— WOODWORTH, J. B. The Ice Contact in the Classification of Glacial Deposits. From the American Geologist, Vol. XXIII. February 1899.

ERRATUM

On page 38, eleven lines from the top, instead of "*are frequently found one foot*," read "*are sometimes found one-half mile*."

THE

JOURNAL OF GEOLOGY

APRIL–MAY, 1899

THE VARIATION OF GLACIERS. IV[1]

THE following is a summary of the third annual report of the International Committee on Glaciers.[2]

RECORD OF GLACIERS FOR 1897

Swiss Alps.—The glaciers of this region are in general in a state of retreat. Of fifty-six glaciers observed, thirty-nine are retreating; five are stationary; twelve are advancing.

Two glaciers have been under observation during a complete period, the Zigiorenove and the Trient. The Zigiorenove had a maximum in 1852; it retreated from then until 1878 (twenty-six years); it then advanced until 1896 (eighteen years), when it had another maximum. Hence its entire period from maximum to maximum amounted to forty-four years.

The Trient had a maximum in 1845; from that time it

[1] The first three articles of this series appeared in this JOURNAL, Vol. III, pp. 278–288; Vol. V, pp.378–383, and Vol. VI, pp. 473–476.

[2] Archives des sciences phys. et nat., Vol. VI, pp. 52–84, Geneva, 1898. At the meeting of the International Committee on Glaciers, in St. Petersburg, on September 1, 1897, Professor Ed. Richter was elected president, and Professor Finsterwalder, secretary, for the following three years. The following investigators were elected corresponding members of the committee: Professor Torquato Taramelli, Pavia; Dr. Thoroddsen, Reykiavik, Iceland; Baron Gerard de Geer, Stockholm; Constantin Rossikow, Wladikavkas; Professor Dr. Sapojnikow, Tomsk; Dr. A. Hamberg, Stockholm; M. Lipski, St. Petersburg; Professor Israel C. Russell, Ann Arbor, Mich.; M. I. Coaz, Bern; M. Chas. Rabot, Paris.

retreated until 1878 (thirty-three years); it then advanced until 1896 (eighteen years), when it had another maximum, which makes its entire period fifty-one years.

There remain still among the Swiss glaciers some marks of the increase of the last quarter of the nineteenth century, but the retreat of the glaciers is now, very generally, in full force.[1]

Eastern Alps.—The important results obtained during the current year in the eastern Alps justify the labor undertaken to obtain them. It has been shown that the partial advance observed since 1885 extends towards the east beyond the Brenner, even as far as the groups of the Venediger and the Glockner; and it is most probable that this is not the result of the great precipitation during the past two years, but is due to some more general cause; for it has been possible to predict it in the case of the Gliederferner since 1892. This same glacier has also given us some information in answer to the question—does the swelling of a glacier move down the glacier more rapidly than the rate of flow of the ice? The reply is affirmative. From 1887 to 1892 the ice had moved a distance of 110 meters, whereas the swelling had advanced 250 meters. When the swelling reached the point at which the velocity was measured, it produced a considerable increase in the velocity of the ice. Similar results are also found with the Vernagtferner.

Of these glaciers we have, definitely, twenty-six advancing, eight stationary, and twenty-six retreating. The retreat seems to be more general as we go further eastward.[2]

Italian Alps.—No results are given for these glaciers, but a careful report is made of the means taken for marking their positions, so that in the future the variations of a large number may be determined.

Scandinavian Alps.—So far as observations go, the glaciers in this region are either stationary or retreating.[3]

[1] F. A. Forel, XVII Rapport sur les variations periodiques des glaciers des Alpes suisses. Jahrbuch des Schw. Alpenclubs, Vol. XXXIII, p. 249. Bern, 1898.

[2] Report of Professor Finsterwalder.

[3] Reports of Dr. Svenonius and Dr. Oyen.

Spitzbergen.—The most important work on these islands is that of Baron de Geer, who has visited them several times. He finds from the maps and photographs that the glacier of Sefström has advanced about four kilometers since 1882, but at present seems to be retreating. On the other hand, the glacier of von Post has retreated slightly since 1882 Sir Martin Conway found that the glacier, which he called the Ivory Gate, has advanced very considerably since 1870. The best accounts of the observations of Sir Martin Conway's party are found in the *Geographical Journal*, April 1897, and in the *Quarterly Journal of Geology*, 1898, Vol. LIV, pp. 197–227.

Dr. A. Hamberg has written on the parallel structure of glaciers. He thinks that this, as well as the similar structure observed in Antarctic ice, is due to stratification.[1] He thinks, also, that the movement of these glaciers is due to the slipping of successive layers over each other, and that there is practically no differential movement in the layers themselves. Dr. Hamberg thinks that in these latitudes greater pressure is necessary to convert the névé into solid ice than in warmer climates, and he thus explains the fact that many of these glaciers are not very thoroughly consolidated.

Franz Josef Land.—Dr. Nansen tells us, in the account of his celebrated polar expedition, that there are no true glaciers on these islands, but that they are covered with masses of ice sloping toward the sea. These are apparently of the same type as those described by Dr. Hamberg. Dr. Nansen also tells us that he found indications of the existence of a former glacier all along the northern coast of Siberia. He also gives us interesting descriptions of the folding and crushing of the polar ice as a result of ocean currents.[2]

Greenland.—A Danish expedition visited the island of Disco in 1897 and examined the glaciers of Blösedalen, which had been visited in 1894 by Professor Chamberlin. They found that

[1] REV. O. FISHER gave the same explanation of the horizontal markings in Antarctic ice. Phil. Mag. (5) 1879, Vol. VII, pp. 381–393.

[2] Report of PROFESSOR NATHORST.

the two southern glaciers on the western side of the valley have made a marked retreat in the interval, and they established stations for the future observations of these glaciers.[1]

Caucasus.—In this region a very large number of glaciers have been examined and photographed. They show a marked state of retreat.

Turkestan.—Twenty-six glaciers have lately been discovered and described by Dr. Ivanow in the mountain chain of Talassk-Alataou. They all have a great altitude and show indications of such a great retreat that they may perhaps disappear altogether. Many new glaciers have been examined and photographed in the mountain chain of Peter the Great. They are apparently in a marked state of retreat.

The Altaï.—Professor Sapojnikow has discovered in the last few years five glacier centers in the Altaï mountain. These contain more than thirty glaciers, some of which compare in size with the largest glaciers of the Caucasus. All of them are evidently retreating, but it is not yet possible to give even an approximation to the rate.[2]

A very interesting and full account of our present knowledge of Arctic glaciers and their variations has been published by M. Charles Rabot, under the imprint of the International Committee on Glaciers.[3] After a short account of the characteristics of Arctic glaciers he takes up in detail various glaciers, with references to original sources of information, with the following results.

The glaciers of Grinnell Land appear to have attained a maximum shortly before 1883.

The inland ice of Greenland seems at present to be at a maximum, particularly in the north. In the south a slight retreat is showing itself but too slight to arrest the general advance of the ice which has been going on during the historic period.

[1] Report of Dr. Steenstrup. Dr. Steenstrup went back to Greenland in May 1898 to continue the study of the glaciers there, which he discontinued in 1880.

[2] Report of Professor Mouchketow.

[3] Les variations de Longueur des Glaciers dans les Regions Arctiques et Boreales, Archiv. des Sciences phys. et nat. Geneva, 1897, Vol. III.

The glaciers of Iceland began to advance at the end of the seventeenth century, at which time they were much smaller than at present. This advance continued, interrupted about the middle of the eighteenth century by a hesitating retreat in the case of certain glaciers. After this, most of the glaciers made an extraordinary advance; a veritable invasion of the ice took place, which continued during the larger part of the nineteenth century. After this advance there was a general retreat, though some glaciers are still advancing. The retreat began earlier in the north (1855 to 1860) than in the south (1880). It is less marked than the preceding advance.

There is a large volcano on Jan Mayen Land on which are nine large glaciers. A study of the records of whalers and explorers seems to show that these glaciers have advanced since the end of the seventeenth century.

REPORT ON THE GLACIERS OF THE UNITED STATES FOR 1898[1]

The end of the Eliot glacier on Mount Hood, Oregon, is supported by its lateral moraines, and is much covered with débris. On each side, one or two hundred yards from the end, the ice seems to be breaking through these moraines. This may be due to stream erosion, washing out the moraines and thus removing the support for the ice; or it may mean the beginning of an advance (*H. D. Langille*).

Professor Russell has recently published a most interesting account of the glaciers of Mount Rainier.[2] He describes the characteristics of a system of glaciers on a conical peak. Starting in general from a common névé region the glaciers separate into distinct streams lying in deep channels. The V-shaped intervals between them are occupied by smaller glaciers, which he has called inter-glaciers. He thinks the amphitheaters at the

[1] The synopsis of this report will appear in the Fourth Annual Report of the International Committee. The report on glaciers of the United States for 1897 was given in this JOURNAL, Vol. VI, pp. 475, 476.

[2] The Glaciers of Mount Rainier, Eighteenth Annual Report of the U. S. Geol. Surv., pp. 349–423. A preliminary note on PROFESSOR RUSSELL'S observations appeared in Variations of Glaciers, II.

head of some of the glaciers are the result of glacial erosion; he gives also an interesting account of dome-shaped elevations, much broken with crevasses, which seem to be a peculiarity of these glaciers; they are apparently due to elevations in the bed of the glacier. Professor Russell describes all the glaciers except those on the western side of the mountain. He finds them all very much covered with débris at their lower ends, and notes that there is a general retreat. At one point he noticed that the surface of the Cowlitz glacier, about two miles from its lower end, has recently been lowered seventy-five to a hundred feet, as indicated by fresh lateral moraines deposited on the mountain. The Carbon glacier has receded about one hundred yards between 1881 and 1896, and the Willis glacier about five hundred feet in the same interval. All the other glaciers show a marked diminution, but the amounts were not determined.

Professor Russell has kindly sent me the following account of the glaciers in the state of Washington, which he saw in 1898. It will be noticed that their number is far greater than had been supposed.

Glaciers on the Wenatchee Mountains.—In examining the records of the old glaciers of the state of Washington it was found that the Wenatchee Mountains formed an independent center of ice dispersion from which flowed several large glaciers. One is not surprised, therefore, to find small glaciers still lingering on the higher portions of this rugged and exceedingly picturesque group of granite peaks.

On the summit portion of the Wenatchee Mountains about four miles due east of the culminating pinnacle of Mt. Stuart, there is a glacier measuring by estimate one mile from north to south, including both névé and true glacial ice, and of somewhat less width. It lies on the highest portion of the western rim of a magnificent amphitheater excavated in compact granite. A view into this desolate but wonderfully attractive basin, from the narrow crest forming its eastern wall, is the finest and most instructive picture of its kind to be found in the entire Cascade region.

On the north side of Mt. Stuart, about one thousand feet below its summit, which rises 9470 feet above the sea, there are three small glaciers, situated in steep gorges or clefts in the granite, and sheltered by outstanding cliffs; combined, they would probably make an ice body less in mass than the one described above. These glaciers are narrow, and extend down the gorges where they occur for some two thousand feet. Below each there is a small and fresh-looking moraine.

The glaciers just described derive their main interest from the fact that they are isolated, being some twenty-five or thirty miles to the east of the main divide of the Cascade Mountains.

Glaciers on the Cascade Mountains.—The glaciers of the Cascade Mountains south of the United States-Canadian boundary probably number several hundred, and of these about 100 or 150 have been seen by the writer; but only a few, in the immediate vicinity of Glacier Peak, have actually been traversed. All of them are small; of those seen, probably the largest is not over two miles in length, and by far the greater number are considerably below this measure. Nearly all lie in amphitheaters or cirques. Their principal interest centers in their distribution, their relation to climatic conditions, and the fact that all of those seen are accompanied by evidences of recent recession.

There is one small glacier, however, that is worthy of special study in reference to the manner in which an ice-stream expands when not confined by walls of rock, and in expanding, forms longitudinal, or perhaps more properly, radial crevasses in its fan-shaped terminus. The glacier referred to is at the head of White Chuck Creek at the immediate south base of Glacier Peak, but on the south side of the deep canyon in which flows the branch of the creek nearest to the base of the peak. This glacier flows northward, and is in full view from Glacier Peak. The periphery of its broadly expanded extremity is not over 1000 or 1500 feet by estimate, and is broken by some four or five radial crevasses which are widest on the outer margin of the fan-shaped expansion and contract to narrow clefts which become still smaller, and disappear when traced toward the feeding névé.

This is a typical miniature example of glaciers like the Rhone glacier, Switzerland, and the Davidson glacier, Alaska.

Most of the glaciers on the Cascades have a lower limit of about six thousand feet; the majority of them are west of the Cascade divide, and are either in immediate proximity to or on Glacier Peak and the sides of lateral ridges branching from it; or else on somewhat detached peaks, some of them ten to twenty miles west of the Cascade divide. Of these outlying groups of glaciers, the most numerous are at the heads of high grade valleys in the granitic peaks about Monte Cristo, as has been observed by Bailey Willis, and on similar granitic peaks bordering the upper course of Skagit River. There is also an outlying group of glaciers on Mt. Baker and neighboring mountains.

The broadest névé fields and most numerous glaciers occur on Glacier Peak and the rugged mountains surrounding it. The snow fields in this region cover a rugged area some ten square miles in extent, and are confluent; from this gathering ground there flow several short ice streams, or rather ice tongues, as none of them have a characteristic stream-like form. The névé extends up the sides of the culminating cone of Glacier Peak and occupies the remnant of a crater still recognizable at its summit. From the top of Glacier Peak fully fifty glaciers are in view within a radius of about thirty miles. But little, if any, difference in the distribution of these glaciers can be recognized, on looking northward or southward, thus indicating that their existence depends rather on general climatic conditions, than the occurrence of previously formed cirques, or the shelter afforded by lofty peaks.

Lituya Bay, Alaska.—This bay was visited and mapped by La Pérouse, in 1786. It has the shape of the letter T. The cross arm of the bay was not surveyed but was drawn in from descriptions of the officers who visited it. La Pérouse speaks of five large glaciers coming down to the water, two at each end and one at the side of the cross arm. The maps of the Canadian Boundary Commission, made about 1894, show that the side glacier has diminished, but that the two glaciers at each end of

the bay have coalesced and advanced nearly two miles (*O. K. Klotz*).

Dr. William H. Dall, who visited the bay for the United States Coast Survey, in 1874, thinks that these glaciers were certainly a mile or more shorter then than the Canadian map shows them to be now; so that the advance seems to be still progressing.

Mexico.—The glacier on Mount Iztaccihuatl is advancing (*Ez Ordoñez*).

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March 27, 1899.

NANTUCKET, A MORAINAL ISLAND

A GEOLOGICAL MODEL OF NANTUCKET

THIS model (made at Harvard University), size 18 by 24 inches, scale 1 : 62500, or about an inch to the mile, is based on the United States Geological Survey topographic map of 1887, and on information from the latest geological surveys of the island. It was with the aim of producing an instructive relief of

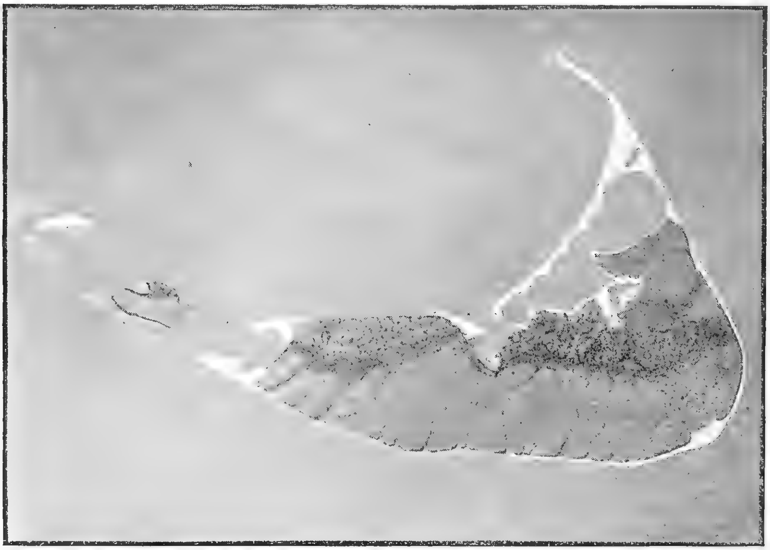
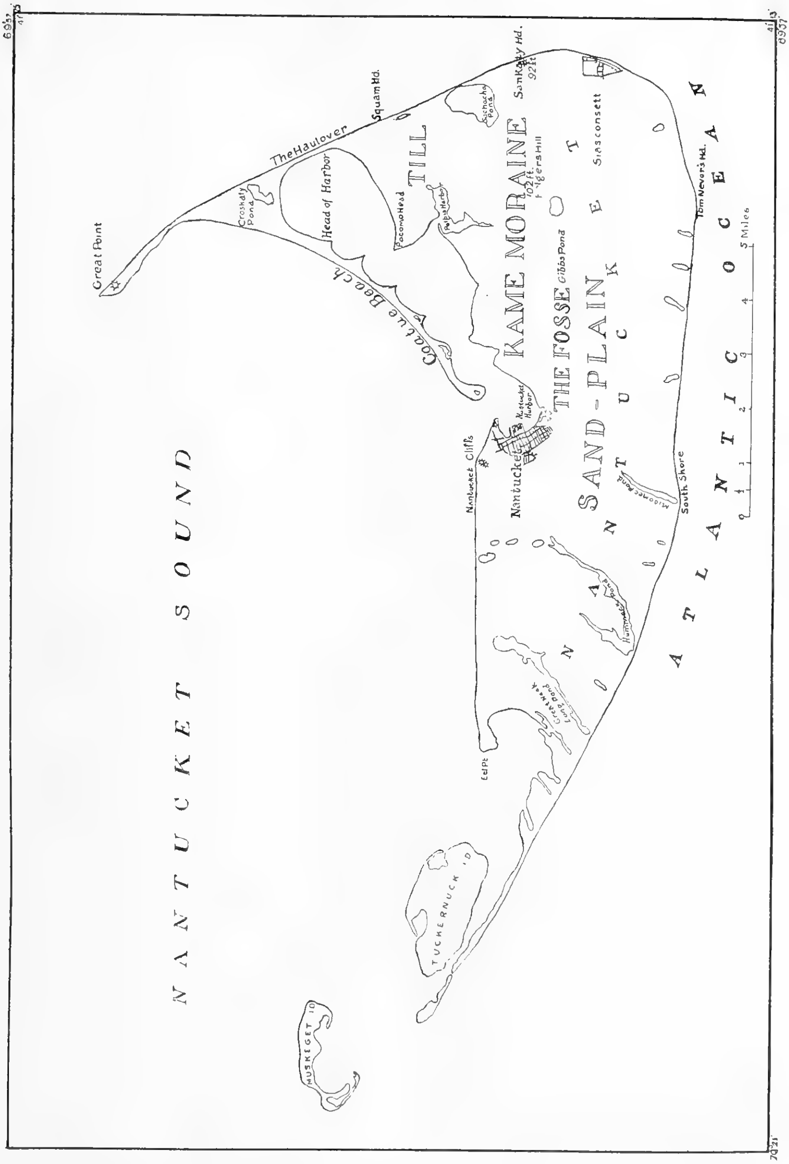


FIG. 1.—A Geological Model of Nantucket.

this portion of the deposits of the great continental ice sheet which here forms a type example of a morainal island, that this model was undertaken.

The principal topographic features,[1] shown by a profile sec-

[1] After report on "The Geology of Nantucket," by PROFESSOR SHALER, U. S. Geol. Surv., Bull. 53, 1889; surveys by J. B. WOODWORTH, U. S. Coast Survey, *et. al.*



OUTLINE MAP OF NANTUCKET.

tion across the island (Fig. 2) may be briefly described under the following divisions.

1. *The ground moraine:* an area of irregularly distributed detritus, the undifferentiated till which lies on the northeast part of the island in the vicinity of Pocomo Head. (See map, Plate I.)

2. *The kame moraine:* a belt or ridge of kame-like mounds and kettles from 20 to 100 feet in altitude, which, running through the middle of the island, seems to form its back bone. On its south side, the kame moraine, descending to the 40-foot level, grades suddenly into a smooth-bottomed trough, which reaches the breadth of over one half a mile in its widest part. The southern side of this depression ascends 40 feet by an abrupt slope into the head of the sand plain. This ditch-like conformation lying between the kame moraine on the north and the sand plain on the south, runs throughout the extent of Nantucket, and Tuckernuck, and has been termed:

3. *The fosse.*—It is supposed that this depression marks the resting place of the ice, while the steep slope rising to the head of the sand plain marks the position of the ice front during the building of the frontal plain, This escarpment at the head of the sand plain has been called *the ice-contact slope*.

4. *The glacial sand plain:* which, falling gently from the terrace at its head to the sea on the south, represents the sand and gravel deposited from the streams as they flowed from the glacier front. The plain has a relatively smooth surface, sloping in its two miles of extent, from the 60-foot level to the cliff where the sea has cut the 20-foot level. At rather regular intervals of a quarter of a mile, the plain is interrupted by shallow troughs. These grade very gently into the head of the sand plain, and continue southward until truncated in their deepest expression by the seashore. These creases are today

Fig. 2.—Profile Section across Nantucket Island.

practically dry, and represent the old drainage channels of glacial time. Some of them can be traced, not only toward the head of the sand plain, but extend quite through the kame moraine to the harbor on the north.

5. *Ponds or lakelets.*—There are several types of ponds on Nantucket. The most prominent lie in the lower ends of the long narrow drainage channels across which the along shore action has built barrier beaches. Hummock Pond, Long Pond, Micomet Pond, etc., are the largest of these basins. Sachacha and Gibbs Pond, by their circular forms alone would seem to be of different origin. Gibbs Pond lies in a depression of the fosse; Sachacha in a depression in the kame moraine across which a barrier beach has been thrown. Croskaty Pond is simply the unfilled enclosure between the trailing spits of Coatue Beach and Great Point. On the inner side of Coatue Beach, lagoon-like ponds have been formed behind the successive growths of sharp cusps. "Three of the cusps on the inside of the Coatue Spit, have no lagoons, but as the other two have, and since they are nearer the end of the spit and hence probably later formed, it is quite likely that the earlier formed forelands also began with lagoons."[1]

Professor Shaler has ascribed these Coatue cusps to tidal whirlpools. He says: "From a superficial inspection it appears that the tidal waters are thrown into a series of whirlpools, which excavate the shores between these salients and accumulate the sand on the spits."[2]

6. *Marshes and swamps* are plentiful and of origin similar to the ponds, the swamps as a rule being but the more advanced stage of pond-filling.

7. *Shoreline topography* is well exemplified. Nantucket's south side shows a coast well straightened by the dominating currents; the irregularities have been smoothed by beaching across the inlets and nipping the sand plain. A large part of the eroded material has gone to build up both the long spit extending toward Tuckernuck, and the rounded cusp or "apron"

[1] F. P. GULLIVER: Proc. Am. Acad. Arts and Sci., Vol. XXXIV, 1899, p. 219.

[2] Bull. U. S. Geol. Surv., No. 53, 1889, p. 13.

which lies between Tom Never's and Sankaty Heads. Greta Point is made from the waste of the cliffs on the eastern side. Coatue Beach represents the tendency of the waves to straighten the north shore.

These shore forms are changing rapidly. The spit, formerly lying in front of Tuckernuck, for example, has been driven back and the island cliffed, sending out two wing bars, the western reaching a little beyond Muskeget.[1] At "South Shore" the foreland has been aggrading, while the blunted cusp near Tom Never's Head has worn nearly away.

Ten years ago Professor Shaler wrote:[2] "About one third of the coast line of Nantucket appears now to be undergoing erosion. At the eastern extremity of the island the erosive action appears at present to be limited to the section from the southern end of the Sankaty bluffs to a point just beyond Haulover Beach at the head of Coatue Bay. In 1873 Professor Henry L. Whiting found by a resurvey of this portion of the shore that the eastern or sea side of the coast at the Haulover had receded by an average of about one hundred feet since 1846. Between Sachacha Pond and the Haulover, especially at Squam Head, the wasting is evidently at this day quite rapid, probably amounting to at least a foot a year. The southern coast westward from Tom Never's Head, especially the section west of Weedweeder Shoal, is also the seat of considerable, though apparently inconstant, wear. A remarkable but probably temporary change has recently taken place in the long spit which forms the western extremity of the island as it is delineated on the Coast Survey maps. Twenty years ago this spit at low tide constituted an almost complete bridge extending from Nantucket to Tuckernuck Island. Of recent years this point has in good part been washed away almost down to its base near Further Creek. It seems possible that the existing separation of Tuckernuck from Nantucket may have been brought about by the action of marine currents within a relatively short time."

[1] U. S. Coast and Geod. Surv. chart, No. 7, 1898.

[2] *Op. cit.*, p. 51.

The following table gives the geological horizons recognized at Nantucket and the corresponding topographic features which are represented in the legend of the model by separate colors.

Postglacial	Recent	Swamps and Marshes Ponds — four types Shoreline; beaches, spits, bars, cusps, cliffs
Pleistocene	Last Glacial Epoch	Ground Moraine Kame Moraine, Fosse, Frontal Sand Plain } Terminal Moraine
	Older Pleistocene	Sankaty Beds, shell deposits
Cretaceous		Clays — artificially exposed (not indicated)

I am indebted to Professors Shaler and Davis, and Mr. M. S. Jefferson, for helpful criticism on this model, and especially to Mr. J. B. Woodworth, whose valuable aid has much increased its merits. G. C. Curtis.

A SKETCH OF THE GEOLOGY[1]

The island of Nantucket, which has been made the subject of a model by Mr. Curtis, is one of the most instructive portions of the terminal moraine of the last ice epoch in North America, because it is the most distinct and isolated of these glacial accumulations. Set in the waters of the ocean far to the south of the morainal belt of Cape Cod, and distant nearly its own length from the neighboring island of Martha's Vineyard, the peculiari-

[1] Written by J. B. Woodworth at the request of Mr. G. C. Curtis.

ties of its glacial form, despite the low relief of the island, are readily discerned.

This island, more than any other one of the New England islands,[1] approaches closely the purely morainic type. On Martha's Vineyard, Block Island, and Long Island, the relief is so far influenced by the topography of folded and eroded beds older than the moraine, that the true morainic expression is not fairly seen. It is in the nature of glacial drift to mask to a large extent the older rocks on which it lies. The drift of Nantucket affords no exception to this statement. Beneath this mantle of till, gravel, and sand, whose relief is shown in the model, there is a basement of pre-Pleistocene clays and older Pleistocene beds, which are exhibited in the sea cliffs on the east coast, and again on the north shore. These pre-morainal beds give rise to certain peculiarities in the topography, forms which even the morainal deposits do not entirely conceal. Remove both the moraine and the plain of gravel and sand on the south side of the island, and these older deposits would still stand above the present sea level as a number of small islands, one at Sankaty Head, one at Squam Head, and a larger islet about the size of Tuckernuck, extending westward from the site of the town of Nantucket. Other small islets might remain where the later drift now covers these older rocks.

The oldest known formation on the island is a bluish clay, probably of Cretaceous age. This clay makes up the ridge south and west of the town of Nantucket. The beds of this series are highly folded, as are also the strata of the same, and even more recent, date in the islands westward to Staten Island. Beneath these beds at an unknown but probably not great depth we should expect to find the extension of the granites and gneisses of southeastern Massachusetts.

Newer than this oldest clay formation is a series of sands and sandy clays containing a Pleistocene marine fauna, that of the well-known Sankaty Head beds. That these beds are older than

[1] A name proposed for the islands from Nantucket westward off the southern coast of New England, having a common geologic and geographic development.

the moraine is shown by the tilting and dislocation of the strata under the Sankaty Head lighthouse, their truncation by erosion and the unconformable deposition on them of the moraine, a relation first described by Upham, who showed that the beds do not belong to the so-called Champlain epoch as Dana was first led to suppose. Northward, at Squam Head, similar beds occur at high angles with folded clays, indicating that a profound disturbance of the strata over the site of the island took place sometime after the deposition of the older Pleistocene. Opinion is not unanimous concerning the cause of this and the similar dislocations which affect the islands of this group. According to one view, the dislocations originated in movements taking place in the earth's crust beneath, being simply a more pronounced phase of the disturbance which marks the "fall line" from New York southward at the inner edge of the coastal plain. Another view supposes the strata to have been disturbed by the mechanical action of an ice sheet advancing upon the soft strata of the Atlantic coastal plain. Since the action took place long before the deposition of the moraine which constitutes the chief feature of the island, the question need not be debated in a paper dealing primarily with the interpretation of a model of these more recent features.

The superficial formations of glacial origin on Nantucket appear in three very distinct belts extending east and west across the island and appearing on the dependent island of Tuckernuck. The small, wave-washed isle of Muskeget is probably a modified remnant of one of these belts. These deposits reappear on the easternmost part of Chappaquiddick. These bands may be spoken of as the kame moraine, the fosse, and the frontal plain. North of the hummocky ground, known as the kame moraine, in the eastern part of the island, is a small area of till-covered land. It seems to be the unstratified débris left upon the surface when the ice-sheet melted away, and may be dismissed with this explanation. Everywhere bordering the island is a fringe of recent marine deposits, in the making of which the original outline of the island has been much altered.

The significant features in the glacial formations are assembled in the accompanying diagrammatic cross section.

It is most convenient to consider the frontal plain first in describing the above named features of the island. This plain begins rather abruptly on the north as a terrace overlooking a more or less depressed region. The height of the plain along

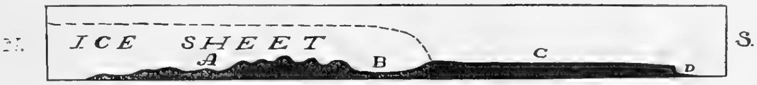


Fig. 4.—Cross section (diagrammatic) of the Island of Nantucket, showing the relation of the kame moraine (*A*), the fosse (*B*), and the frontal plain (*C*). *D* is the present beach. The dotted line represents the supposed profile of the ice sheet when the frontal plain was building.

this summit line is, where greatest, about 60 feet above the sea level. The slope of the terrace to the fosse on the north is well marked, but not so steep as that of the typical moraine terrace of Gilbert,[1] or so sharply cuspate as the ice-ward edges of the sand plains described by Davis[2]. Yet this slope taken in connection with the fact that the plain inclines southward with well defined drainage creases, and that the materials are coarse at the crest line and grade into finer gravels and sands southward, affords good evidence that the plain was built against the front of the ice-sheet by excurrent streams. Viewed in this light, the terraced head of the plain indicates the east and west line along which the ice front stood in its southernmost extension.

This ice-contact slope is most distinct in the eastern part of the island, where it turns to the southeastward, as if the ice sheet extended seaward in this direction, covering at least the area now forming the Nantucket shoals. In the vicinity of the town of Nantucket, the hillock of pre-Pleistocene clays already mentioned has given rise to the type of sand plain which is dominant on Martha's Vineyard, one in which for the greater part of that island, the top of the sand plain was not built up to the base of the ice front where that rested on elevated ground. On the

[1] Lake Bonneville Monograph 1, U. S. Geol. Surv., 1890, pp. 81–83.

[2] Bull. Geol. Soc. Am. Vol. I, 1890, p. 195.

western part of the island and again on Tuckernuck, the ice-contact slope can be distinguished, affording a base line of reference from which to work out the relations of the glacial deposits to the ice sheet.

Accepting the slope at the head of the plain as denoting the position of the ice front, it follows that the fosse and the kame moraine are features originating in the area occupied by the ice. The fosse is simply the unfilled ground between the head of the plain and the belt of accumulations known as the kame moraine.

The kame moraine is supposed to be contemporaneous with the sand plain; one was building up by the action of excurrent streams outside of the ice while the other was accumulating inside the ice by the combined action of ice and water. This idea that the kame moraine is not frontal but submarginal in relation to the ice sheet by which it was built, first suggested, it is believed, by Salisbury for certain portions of the terminal moraine westward on the mainland, is consistent with the interpretation which has been placed on the origin of the kames near the heads of sand plains. Both ice-laid and water-laid drift tend to accumulate in the form of knobs and basins in this situation. At present, the explanation of the phenomenon can hardly be said to rank as an hypothesis, much less as "demonstrable theory."

One supposition is that the kame moraine marks the site of an earlier frontal deposit, *e. g.*, a sand plain, subsequently overridden by the ice sheet in its advance to the line marked by the head of the frontal plain. Stratified beds of sand and gravel seen under a coating of till in patches of kame moraine, as at Bridgewater, Mass., and the sandy clays under the till of the Nantucket kame moraine, show the possibility of the extra-glacial origin of the original deposit. But this explanation does not account for the seeming regularity in the occurrence of the belt of kame moraine at a distance of from half a mile to a mile back of the head of the outwash plain.

A second supposition makes the kame moraine built up under the lip of the ice sheet in the manner in which débris was seen

accumulating in that situation by Chamberlin in the Greenland glaciers. Applying the observations made by Chamberlin upon the shearing of the upper ice over the lower and the involution of drift which thus comes about, to the case of the Nantucket type of terminal moraine, we may fairly suppose that when the moving ice sheet became blocked against the head of its growing sand plain, the upper ice began to shear over the lower, blocked prism of ice lying behind the sand plain. This shearing movement affected the lower part of the ice sheet for a long distance back from the actual front. At a distance of from one

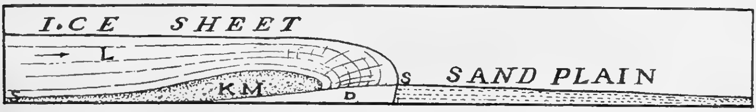


FIG. 5.—Diagram showing supposed mode of accumulation of Kame moraine. *D*, Prism of dead ice blocked by sand plain barrier. *L*, Live ice dragging up drift into K M, the position of the Kame moraine. *S S*, Principal plain of shearing.

to two miles back from the front the bottom ice began to glide over the prism of dead ice lying back of the sand plain. (See Fig. 5.) As a result of this action the subglacial till dragged along on the bottom northward of this belt was gathered in the shear zone with moving ice above and dead ice below. Most of the till accumulated within a belt about a mile wide, leaving a strip in the case of Nantucket from a mile to half a mile wide between this accumulation and the head of the sand plain in which the débris was small in amount as compared with that deposited in the sand plain on one side and in the moraine on the other. On the melting out of the ice sheet, this outer part of the stagnant prism of ice, which was relatively free from drift, would give rise to the depression which separates the sand plain from the moraine. The melting out of the inner thin portion of the wedge of dead ice with its charge of till would result in the hummocky topography which gives the moraine the striking resemblance to a belt of kames. In the case of the water-worn gravels and sands which accumulate in this belt, it is to be supposed that in the shearing movement of the upper ice over the

lower stagnant prism of ice, the subglacial drainage is interrupted and the detritus is involved in the movements of the ice as in the case of the till. It is favorable to this view that, in cases where such action may be invoked, eskers are absent, and the sand plain appears to have been fed by streams flowing off the ice sheet.

Certain ponds and furrows which lie in the kame moraine belt show that the drainage of the ice sheet, perhaps a late phase of the system, coursed through the field quite independently of the motion of the ice, which may well have been stagnant at the time. On the east, the furrow connecting Polpis harbor with the drainage crease in the sand plain has been noted by Shaler, as an indication of the movement of subglacial water as in a pipe to the front. On the other hand, creases west of the town connecting with deep, pothole-like ponds in the moraine belt suggest the holes at the bottom of falls of water off the edge of the ice sheet rather than depressions due to the melting out of blocks of ice.

The question of sea level in relation to the sand plain at the time it was building is a debatable one. The absence of anything like wave action on the island above the present sea level is presumptive evidence that the sea has not stood higher than it now does upon this coast since the glacial formations were deposited. A comparison of the Nantucket plains with the deltas of glacial rivers such as those of the Malaspina district in Alaska and of Heard Island in the Indian ocean would lead us to regard the sand plain as made in the open air.

The student who is desirous of studying many interesting details concerning the geology and physical geography of this island should supplement this brief account of some of its features and the questions which they raise, by reading Professor Shaler's report on its geology.[1]

J. B. WOODWORTH.

[1] The Geology of Nantucket. Bulletin No. 53, 1889, U. S. Geol. Surv., pp. 55. 10 plates. By N. S. SHALER. This work gives references to numerous other papers concerning the paleontology and moraines of the island.

BEACH CUSPS

A FREQUENT feature of our New England beaches is a succession of stony or gravelly cusps with sharp points toward the water, situated on the upper part of the beach where the waves play only at high stages of the tide. My attention was first called to these cusps by Mr. J. B. Woodworth, of Harvard University, under whose direction the general view, Fig. 1, was taken for the U. S. Geological Survey. Subsequent study on Lynn Beach, Mass., where I obtained twenty instantaneous wave photographs, has satisfied me that on that particular shore the cusps must be ascribed to the agency of the seaweed piled up on the beach, modifying the action of the greater waves. The successive stages of construction shed so clear a light on the local

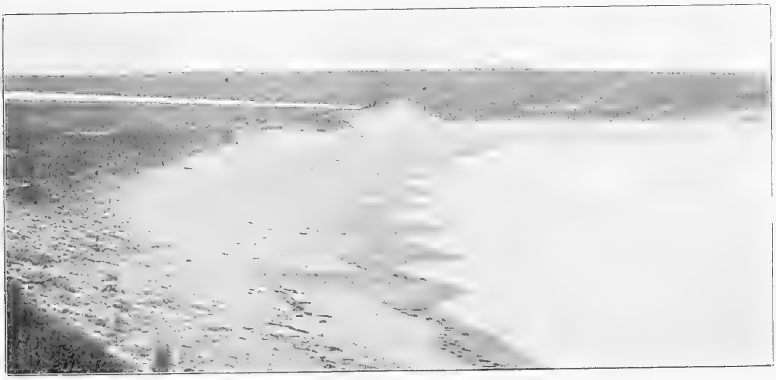


FIG. 1.—Westquage Beach, R. I.

forms, and the weed control has seemed so clear through a great variety of details observed on this beach during more than two years, that it seems time to call the attention of other observers to the point involved. Any beach photograph may have a record on it of some stage of these beach cusps.

The portion of Lynn Beach where these studies were made

is at the junction of the Nahant barrier beach with the mainland, about one hundred yards north of Hotel Nahant. It opens to the Atlantic a little south of east and is on the Boston Bay sheet of the topographic map, in latitude 42° 27′ 30″, longitude west 70° 56′ 7″. A masonry wall with a concrete walk above here caps the beach. Just below this is a mass of rounded stones from two to six inches in diameter, which have been flung up in storms. These are attached to seaweed, having been derived from the bottom off shore.[1] This belt of cobblestones passes into the sand of the beach proper by the series of cusps above mentioned. The seaward side of the heap of cobbles is, as it were, eaten out in bays, twenty to thirty feet wide with residual points of cobbles between. In the bays, the slope descends one foot in four to the almost level beach of fine sea sand. Along a line roughly tangent to the bay heads, and thus cutting across the stony promontories between, there is found an almost continuous wall of seaweed. The bays in the cobble line are floored with a gravel of texture intermediate between the stones above and the sands below. The stony points terminate in slopes much steeper than the bay floors. The gravel of the bay floors itself advances upon the beach in a series of capes, well outside the stony points and alternating with them.

The outer undulating margin of the gravel points on the sand is usually thinly strewn with cobbles from the belt above. These details may be made out more clearly with the help of the accompanying diagram, Fig. 2. The constant *recurrence* of bay and point as one walks along the beach suggests that there is a regularity in width of intervals. This is not so, however, on Lynn Beach, as appears from the diagram, measures from point to point along the beach being 21, 20, 18, 16, 22, 17, 6, 7, and 22 paces. Fainter cusps farther south toward Nahant show similar irregularity. It might be said, however, that on Lynn Beach they are commonly about twenty paces wide.

The work of the waves on the beach depends on their magnitude and direction, and on the stage of the tide. The magnitude

[1] SHALER: National Geographic Monographs, Beaches and Marshes, p. 144.

of the waves varies primarily with the wind. The great rollers that tumble up a beach some days of calm are due simply to a distant wind whose effect is transmitted faster through the water than through the air. For beach work, however, we must distinguish two orders in the magnitude of waves that follow each other even in a brief period. Anyone who visits a beach may satisfy himself that at fairly regular intervals there occurs a great wave, far overtopping the average in height and extent of

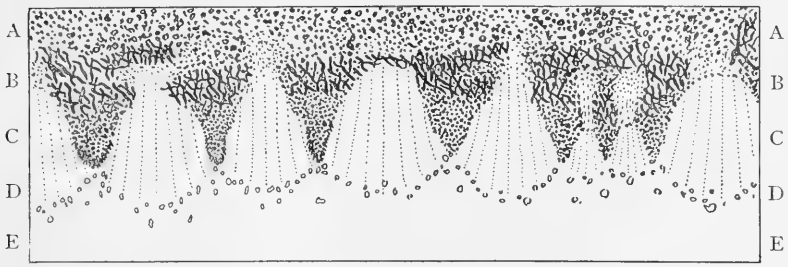


FIG. 2.—Diagram of Beach Cusps.

AA Zone of Cobbles. CC Stony Cusps.
BB Zone of Seaweed. DD Gravel Cusps.
EE Flat Beach of Sand.

advance up the beach. Now this great wave is as much more efficient than its fellows for beach work in ordinary weather, as the work of a single storm outweighs months of normal tides in building and modifying features of shore topography. As regards the stage of the tide, in a similar way, spring tides are the occasions of maximum beach work in average weather. This is especially true in all that concerns the upper beach line, where our gravel cusps are situated. All the waves, great and ordinary, have an excess of shoreward over off-shore movement during rising tide. Generally speaking it is thus during the rising of the tide that objects are driven up the beach, and during the fall that they are drawn out seaward, unless left stranded, as must happen in most cases, since both forces, though opposite in direction, have least intensity at the shoreward margin of the beach.

It results from these considerations that the greatest amount of stones and seaweed will be flung up on the upper beach on the rise of a spring tide when a strong gale is blowing from the east. The beach is not, however, a convenient place for observation at such a time, nor can it be visited save by observers resident in the neighborhood on account of floods and washouts that result and interrupt railroad and other travel. For this reason it is more practicable to study what occurs during spring tides with only moderate winds.

Such an ocasion was November 7, 1896 when I was fortunate enough to reach the beach shortly before high tide. The ordinary waves were playing up and down the bays as far as the belt of seaweed, *BB*, Fig. 2. These waves advanced with a front indented by the stony points at their maximum advance. But at intervals of about ten minutes a great wave broke evenly upon the line of seaweed, sending tons of water over the cobblestones above. The zone of seaweed in the diagram should be understood to have a depth of 12 to 18 inches. Shoreward from the crest, the weed slopes and thins. It is more or less present even on the cobble belt *AA*. But the zone represented on the diagram marks the crest. Immediately after breaking, the wave outside the zone *BB* retires, leaving considerable masses of water imprisoned behind the weed. This can only escape through occasional breaks in the wall of seaweed and at these points streams of considerable strength set outward. This moment is recorded in Fig. 3. The wave has just broken evenly along the whole line. At the instant represented by Fig. 3 the water may be seen pouring toward the opening from right and left behind the weed, streaming out through the break in the weed whence the water is distributed fan-like in every direction. A similar fan in the water to the left indicates the opening of another outlet through the weed. The quantity of water flung behind the weed barrier when such a great wave breaks is sufficient to maintain a strong current through the outlet during the rise and fall of several ordinary waves, which only play up and down the bays. As the great wave recedes we note the stony promontories,

which are completely buried in Fig. 3, and the bays between. We also note that each break in the seaweed exactly marks a bayhead. The gravel cusps below are still beneath the water. On one occasion I saw a continuous wall of seaweed flung upon the beach, saw the water ponded behind it until finally weaker points in the wall yielded to the pressure and broke, and openings were established that guided the outflow of all subsequent great waves. It seems to be clear that the bays between

FIG. 3.—Moment of wave retreat.

the stony promontories are scoured out by water escaping from behind the barrier above. That weak points should occur is inevitable. It is not conceivable that the waves could cast up a line of weed so perfectly homogeneous as to present the same resistance to outflowing water all along the line. Once a current is established across the crest, its lightness causes the weed to float away in the stream until the pebbles below are bared, and then washed down the beach in the narrow rushing stream. The weed where unbroken protects the stony ridge as the paper pattern protects glass from the sand-blast. Furthermore it concentrates the water on the unprotected spots. It may be thought

that a stony barrier might play a similar part on a beach where seaweed was absent. Great waves would surmount the crest and the water caught behind escape as best it might to the sea. Low places would doubtless occur in the crest of the line and some water flow over them. But it is to be expected that the water would filter through the mass rather than wear channels, owing to the greater specific gravity of the barrier. It is unlikely that bays could be cut out in the stones under such circumstances. It would seem to follow that such stony cusps are to be looked for only on coasts where seaweed or some similar material is abundantly thrown up.

As the tide falls, presently the waves cease to surmount the crest of the weed and each wave in receding discloses more and more of the lower beach. It now becomes evident that the scouring waters that have been rushing down the bays have spread the gravel with which they are visibly loaded in a great fan at the mouth of the bay, fairly underlying the wave-fan seen in Fig. 3, outside the seaweed. It is a true fan delta built by the stream where its waters are checked by the relatively stagnant waters outside. As these deltas are built out in front of the bays it results that in this outer line of points bays occur opposite the points of the inner stony promontories. This is at once clear on the diagram (Fig. 2). Walking along the beach at low tide the delta fans are seen nearest and are more in evidence than the stony or original cusps above. These upper cusps may well be called *residual*, as they are remnants of a continuous line in which the bays have been scoured out here and there. At Lynn the residual cusps are stony but that is not essential. In Fig. 1, the whole material is apparently fine beach sand. The seaweed that originated the form is here hardly visible but enough is on hand to show that it occurs on the beach. Attention should be called here to the fact that seaweed shrinks enormously on drying. I have made no measurements and have no data at hand, but sugar-cane, with which I am familiar, contains nearly three times as much juice as wood, and cane has certainly more woody fiber than most seaweed. For this reason

a heap of weed that may while fresh considerably modify the waves, may become quite inconspicuous when dry. Considerable quantities of weed are also carted from the beaches for manure. The only sure way to determine the presence or absence of seaweeds on a beach is to visit it immediately after on-shore storms have torn up the bottom just beyond the low tide mark. The residual cusps in Fig. 1 are rendered unusually

FIG. 4.—Residual and Delta Cusps.

visible by the wetting of a portion of their line in what seems to be an ordinary wave of a rising tide. The original photograph shows the delta cusps distinctly alternating with the residual cusps above. At Gay Head I have seen only the residual cusps, which are there constructed of pebbles an inch or two in diameter and derived from the till topping the cliff above. At that time the form was unintelligible to me, but now I am sure that at lower water the delta cusps will be seen at Gay Head too.

In Fig. 4 both series are well shown on Lynn Beach. The water stands in the hollows between the delta cusps, which show only their points on the left. The view was taken about two hours after high water. Half an hour later the waves break far

out on the beach, and only a steady trickle of water draining out of the ridge of stones and seaweed remains, in place of the violent rushing at high water. The contact of the delta cusps with the flat beach is now disclosed, and we see the cobbles already referred to strewn along the margin of the cusps (Fig. 5). The view is taken from a point on the edge of the flat beach itself and shows only the delta cusps, the residual cusps lying off farther to the left. The cobbles have probably come down the bays in the rushing streams that build the deltas. They are scattered quite at random at the foot of the delta slopes, as indicated in Fig. 2. The advancing waves of the next tide will doubtless drive some of them up the promontories on which the earlier waves are concentrated by the delta cusps.

But if the establishment of bays in the ridge of cobbles is to be ascribed to the great waves, the part of the ordinary wave is not therefore to be neglected, nor the waves of lesser tides so long as they send the water at all into the region affected. The ordinary waves intensify the form given by the gaps in the seaweed. Across the beach below all waves advance in long, even lines. As these come to the delta cusps their front is broken into tongues which are concentrated into the outer bays and made to impinge on the residual cusps in advance of the water which comes to the inner line of bays. Of all the details of the wave-work, this is one of the best established. As the wave thus concentrated on the stony promontories tries to surmount them, it is more and more deflected to right and left by the steepness of the cusps. Thus, when the wave recedes, almost all the water runs down the inner bays. This was first seen at Gay Head, where I have a record in photographs. The bays thus have a preponderance of seaward scour. On Lynn Beach this point was studied by gathering bricks along the shore and throwing them in front of the points of the stony promontories. Of twenty bricks cast into the sea where the two fans meet in Fig. 3, corresponding to the second stony point from the left in Fig. 2, one went across into the bay alongside with the next incoming wave; then a great wave brought all over the ridge of seaweed.

Some at once went on down into the bay alongside, whence they were finally removed seaward by the play of ordinary waves. Of a hundred stones flung into one of the bays, more than half were carried seaward in twenty minutes, and the others were half buried in the gravel by the scouring water digging pits in front of them. On another occasion my hat blew into the water in one of the bays, and in spite of some wind off-shore, was soon cast up on one of the promontories. There is some travel of

FIG. 5.—Delta Cusps and pebble fringe.

material shoreward up the promontories and much travel down the bays toward the sea. The great wave drives a good deal of material on shore.

The cobbles that descend over the fan deltas to the beach margin, and again ascend the promontories at the next high water, do not necessarily return to the point in the stony belt above from which they descended. It is probable that with winds setting more or less obliquely along a beach the descents will be made constantly to the right or left of the descents. I think I have seen something of the sort on Lynn Beach, but the observations were not sufficiently continuous to make this certain. In this case each cobble is liable to travel *epicycling* along

the beach, now up, now down, but always along in some lateral direction. In this form a short journey along the beach means a much longer journey along the actual path of travel, and longer opportunity for the attrition that comminutes all beach material.

On any beach where cusps occur the waves may be seen scouring out the bays and building fan cusps below. If it be asked how this begins, the answer must be that the beginning is as old as the beach. When first a ridge of cobbles was flung up by the waves and seaweed driven upon it with the rising tide, there came a moment when a great wave broke on the ridge crest to send a rush of water further shoreward. This water escaping guided the scouring of the first bays in the stony ridge. In these the waves will continue to play, deepening the scour ways, lengthening the delta cusps, and working over and modifying the mass till another spring tide or another on-shore gale builds a new barrier with stones and seaweed newly torn from the bottom, Each set of cusps may modify its successors. A new crest of seaweed flung up today is likely to have its weak points in some measure determined by the previous channels. In violent storms it is doubtful if this control is significant. Each storm probably sets the shape in which the waves must play for a long time.

As these studies have been made at a single beach, though confirmed by some observations from Gay Head and Narragansett Bay, corroboration or modification of the interpretation by others would be welcome.

MARK S. W. JEFFERSON.

A CERTAIN TYPE OF LAKE FORMATION IN THE CANADIAN ROCKY MOUNTAINS

In the Rocky Mountains of Canada there are abundant evidences of the great Pleistocene ice invasion. During considerable travel with pack horses through the valleys of the most easterly or summit range the writer had occasion to cross the continental divide by five different passes, from the Simpson Pass on the south to the Athabasca Pass on the north. This gave a familiarity with the range through a degree and one-half of latitude, or from 51° to 52° 30′ N. The evidence was everywhere so constant that a more extended region would undoubtedly reveal the same indications of a former ice sheet.

The general topography of the Rockies in this region is exceedingly rough, the mountains being disposed in long ridges, with peaks from 8000 to over 13,000 feet high, with deep, narrow valleys between.

In order to understand the special type of lake formation to be discussed, it is necessary first to review briefly the general results of former glacial action in the region. These results are evident in the drift, striations and grooves, the transportation of erratics, and in glacial contours.

Drift, consisting of unstratified clay deposits containing angular and glacially striated stones, covers the valleys and passes throughout the region examined. It varies in thickness from a thin layer up to observed sections of more than 300 feet. It is generally thickest in the valley bottoms and on the lower slopes of the mountains up to an altitude of about 500 feet above the stream beds. Above this level it gradually thins out, leaving the mountains bare at from 1000 to 2500 feet above the valleys.

Drumlins occur in many valleys, especially in those now occupied by large streams, and in some regions are so abundant as to become the most prominent feature of the landscape.

The phenomena of crag and tail, like the drumlins, are very constant and no less important in determining the direction of the ice movement. Crag and tail assumes all gradations between ridges several miles in length to those that are merely shallow accumulations of drift in the lee of slight elevations of the rock surface.

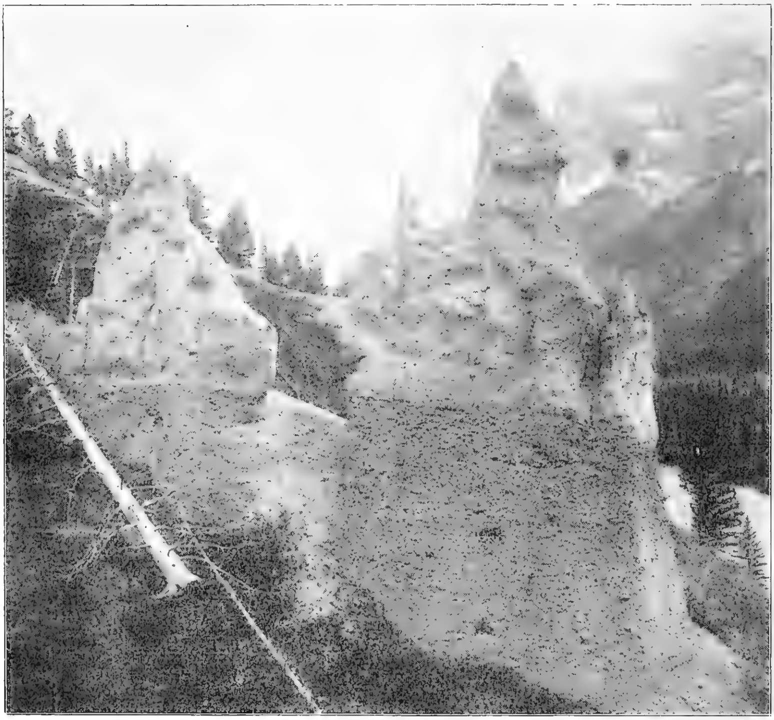


FIG. 1.—Section near Banff showing two tills.

Terminal moraines, except near existing glaciers, are far less frequent than the subglacial drift formations. Modified drift and river terraces are well marked on all the rivers as soon as they reach the plains; also in the mountain valleys of the Athabasca, Saskatchewan, and Columbia; but the smaller rivers and streams rarely show well defined terraces in the mountains themselves.

Several exposures of the drift showed evidence of two ice invasions. One of the clearest of these was discovered on the banks of the Bow River, two and one half miles east of Banff Station, on the Canadian Pacific road. Here the river sweeps against its north bank, and has laid open a section of drift more than 300 feet thick. About half way up the bluff the line between two different kinds of till is clearly marked.

The lower till is of unstratified drift, consisting almost wholly of pebbles and gravel, with but very little clay and rock dust. Quartzite, limestone, and argillite pebbles, many of which are markedly striated, make up the principal mass.

The overlying till consists almost wholly of clay, so hard as to resemble sun-dried brick, which, when struck by a stone resounds like solid rock. Interspersed at considerable intervals are pebbles not differing much from those of the lower till. Like them they are angular and striated. The bottom of these formations is not exposed, as the river rests on drift. However, two formations were later observed on the Cascade River two miles distant, which were identified as the same, and these rested directly on the Cretaceous sandstones of the vicinity. Thus only two tills are represented in this region.

The sides and summits of mountains must be examined for evidence of greater depth in the ice currents than those given by the drift formations. Near the station of Banff, which is in the Bow or South Saskatchewan Valley, about twenty-five miles from the point where the river leaves the mountains, there is a low mountain whose summit is exactly one thousand feet above the river. This mountain is of Devonian limestone throughout, and in form is a blunt ridge running transversely across the valley and partially blocking it. On the top of this mountain there are many Cambrian quartzite bowlders and other erratics which have been transported thither. The nearest point at which these quartzite bowlders are found in place is at Castle Mountain, seventeen miles up the Bow Valley. The limestone ledges are channeled, grooved and striated, in a direction exactly across this mountain, but parallel with the valley.

This mountain, therefore, must have been so deeply covered by a glacial stream that a barrier one thousand feet high caused no deflection of the current.

Proof of higher points being overrun by the ice was observed on Stony Squaw Mountain, which rises to a height of 6130 feet, or 1620 feet above the Bow Valley, and is a little to the northwest of the point just referred to. The mountain has contours rounded by ice action and the higher parts are free from débris or soil except for a few quartzite erratics, of which one, more than two feet in diameter, was found on the very summit. This mountain also is of Devonian limestone formation and consequently the bowlders have been transported hither by glacial action.

The mountains in the neighborhood of Banff show glacially rounded contours much higher than the summits of the lesser points just referred to. Grooves running parallel to the valley direction may be observed on the limestone cliffs of the mountains, from the valley bottom itself, especially in certain conditions of the light. Some of them are between 7000 and 7500 feet above sea level, and indicate that the ice was between 2500 and 3000 feet thick in this region. Up to 7500 feet above the Bow Valley at Banff, the evidence of general ice action is quite certain, but higher than this all is more or less obscure. A distinction must be made between the work done by local glaciers of the mountains and the general currents filling the valleys, but this is not usually difficult as local glaciers, unlike the general currents, were affected directly by the mountain slopes.

Evidence from other parts of the mountains is in accordance with these conclusions. Thus near Lake Louise, forty miles northwest of Banff, in the Bow Valley, striations of a general ice current were found on the summit of a mountain 7350 feet above sea level. Glacial contours are evident about 350 feet higher, or 7700 feet above sea level.

Continuing up the Bow Valley about ten miles, glaciated contours reach an altitude of about 8000 feet. Fifteen miles further up, where the river takes its source, near the Little Fork

Pass, the altitude is still higher, and reaches 8500 feet above sea level. On the other side of the pass in the valley of the Little Fork of the North Saskatchewan, the evidence is almost identical, but with a downward slope of the ice line as the valley descends to the northwest.

The highest erratic was found on a point near Mt. Assiniboine, about twenty-five miles south of Banff, on the summit of a mountain of limestone formation 8650 feet above sea level. In the course of very many mountain ascents no transported bowlders were ever observed at a greater height than this, nor on isolated summits over 9000 feet above sea level were there any evidences of general glacial action.

The indications of former large ice streams which occupied all these mountain valleys are found not only in the Bow Valley but in the tributary valleys of the Saskatchewan and Athabasca on the eastern side of the summit range, and of the Columbia on the western side. In fact no mountain valley was observed in which the same evidence was not more or less apparent, and the line between glaciated and unglaciated surfaces rarely or never appeared at an altitude lower than 7000 feet nor higher than 9000 feet. This ice line is invariably higher in regions of great elevation, near high mountain masses, in elevated valleys and on mountain passes. It is evident then, from the arrangement of drumlins, crag and tail formations, glacial grooves and striations, and the transportation of erratics, that the present drainage system was that of the ice currents, even at the time of their maximum development.

To this there are some interesting exceptions, as for instance, in the Columbia Valley, where it appears that the ice formerly moved southwards and the river now flows northwards. To find a satisfactory explanation is not difficult. This valley is exceptional among the mountain rivers in having very little gradient so that the river is sluggish and the valley is more or less swampy. In other words, it would require only a slight elevation of the region to the north or a depression to the south to reverse the direction of this stream. It is not necessary, how-

ever, to assume such a change in elevation, as a slightly greater precipitation in the north would have made this valley discharge its glacier to the south.

We have then, the following, as a summary of the indications of the nature of former glacial activity in this part of the Canadian Rockies:

1. Evidence in the drift formations that glaciers formerly occupied all the mountain valleys.

2. Evidence in certain till exposures that there were at least two distinct ice invasions.

3. Evidence from glacial contours, striations, grooves, and erratics no less than from the absence of them on isolated peaks over 9000 feet high that the former glaciers were between 1500 and 3000 feet in thickness, that their maximum height in the valleys was between 7000 and 9000 feet above sea level, and that the maximum glaciation of this region was always confined to the valleys, above which the very elevated regions and mountains, which were centers of dispersion, rose like islands.

4. Evidence, from the above, that the present drainage system represents approximately the direction of the former ice currents.

Having thus very briefly reviewed the extent of the ice invasion in the Canadian Rockies within the latitude specified, it is now possible to get a clearer idea of the special type of lake basin which is the subject of this article.

Lakes, though very numerous, are limited in size as would naturally be expected in a region of narrow valleys and steep gradients. The two Bow lakes at the sources of the river of that name, are each about four miles long by one mile wide. Outside of these lakes the great majority are smaller and are of all dimensions down to mere pools two or three hundred yards across. About one hundred of these lakes were more or less thoroughly examined and, in regard to their formation, may be divided into four classes.

1. Lakes formed in kettle holes of the valley drift, often in chains of three or four together. In this class should be included

all lakes where water has collected in irregularities of the drift. These are especially numerous near the summits of passes where the nearly level surface has not permitted the streams to cut down and drain the basins. This class of lakes shows no

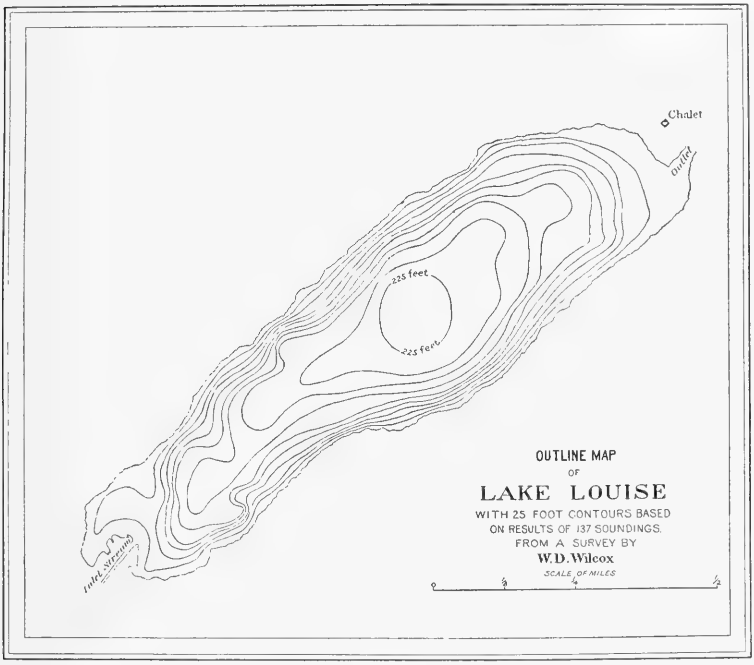


FIG. 2.

regularity of form or location. Their basins are usually shallow, and they frequently have neither inlet nor outlet.

2. Lakes dammed by terminal moraines. Only two of these were found distant from existing glaciers. Each was about a mile long and the dam of one was two miles from the end of a large glacier and that of the other about four miles.

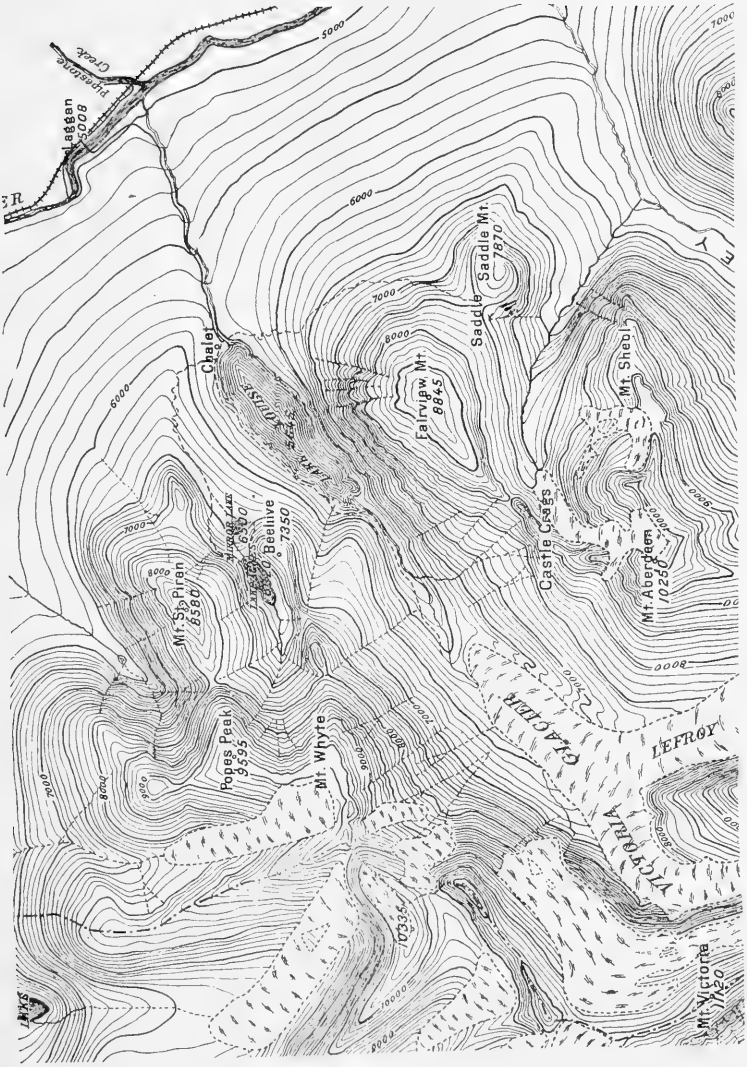
3. Rock basin lakes. Only two of these were observed, one of which was a typical cirque lake. Many rock basin lakes, however, in this region are partially dammed by drift desposits, or are otherwise of complex origin.

4. Lakes found just within the mouths of tributary valleys. These lakes are the most constant of all in their outline and position. They are invariably found where a lesser valley joins a larger one and occupy the mouth of the lesser valley. They are usually leaf-shaped and from three to ten times longer than wide.

Of this type Lake Louise is a good example and was made the subject of special study. Lake Louise is in one of the tributary valleys of the Bow River about twenty-five miles below its source, in latitude 51° 30′ N. and longitude 116° 15′ W. The shore line was carefully surveyed and mapped, after which the basin was studied by means of soundings. The accompanying map of this lake on which the contours represent the depression of the bottom below the surface, shows that the basin is very deep in proportion to its size. The basin is U-shaped with a nearly flat bottom, and with exceedingly steep sides approaching in many places a slope of forty-five degrees.

The lake occupies the end of a valley just above its junction with the much wider valley of the Bow. The catchment basin draining into this lake is an exceedingly rough part of the Rockies, with peaks over 11,000 feet high, forming part of the continental water-shed, at the valley end. The surrounding mountains are covered with considerable fields of ice, which unite to form a glacier about three miles long, measured up either one of its two branches.

A stream from the glacier has carried in clay and gravel so that a delta has formed, and filled in the upper part of the lake basin to the extent of one third of a mile or more. The fine mud carried by the glacial stream which is not heavy enough to sink at once upon reaching the quiet waters of the lake, remains suspended in the lake throughout the summer, and turns its blue-green water to a milky color by the end of August. In November the lake freezes, the inlet stream is much reduced in volume, and becomes clear, and the exceedingly fine mud settles to the bottom. This settling process continues under a thick protection of ice and snow for six months, and with few or no


Pipestone Creek
Laggan 5008
Chalet
Lake Louise 5645
Fairview Mt 8845
Saddle Mt. 7870
Saddle
Mt. Sheol
Castle Crags
Mt. Aberdeen 10250
Mt. St. Piran 8580
Beehive 7350
Popes Peak 9595
Mt. Whyte
10335
Victoria Glacier
Lefroy
Mt. Victoria

convection currents to disturb the quiet of the waters, the lake becomes perfectly clear by spring.

An attempt was made to get a section of these clay deposits at the lake bottom and so determine the age of the lake. It seemed probable that by knowing the thickness of the annual deposit, and by getting an entire section, the number of years since the formation of the lake could be estimated. For this purpose a piece of iron pipe about one inch inside diameter was heavily weighted and fastened to a stout rope. This was lowered in about two hundred feet of water and allowed to fall the last fifty feet so as to carry the pipe far into the bottom. Upon lifting the pipe out, and this was accomplished with great difficulty, a core ten inches long was removed from the pipe by drying. Unfortunately this core did not represent the entire section of the lacustrine deposits so that it would have been useless to make estimates on this basis. As had been hoped, however, there were clear evidences of lamination in the slightly different colored bands of clay, though the structure was distorted by being forced into the iron pipe. As nearly as could be counted there were about one hundred bands to an inch, and on the basis of 10,000 years since the last retreat of the ice, these clay deposits would have to be between eight and nine feet thick. With a more perfect apparatus and an entire section, the age of this lake, and consequently the time since the glacial period, might be quite accurately estimated.

The Lake Louise Valley has a trend to the east as it enters the Bow Valley, as though the former ice streams had turned down stream and swept over the flanks of the mountain on the east side of the valley, while the other side shows a sharp ridge of drift descending from the base of a rock buttress 800 feet above the lake. This ridge carries a dam across the valley mouth and slightly deflects the outlet stream to the right. The outlet stream has cut down through this dam and exposed a section of drift from 75 to 100 feet deep. It is typical till of hard, blue clay, with angular or striated limestones, shales and quartzites, distributed through it.

The two valleys to the east which are similar to the Lake Louise Valley in size, direction and general features, have no lakes similarly located, but there is a more or less pronounced drift ridge on the upstream side of each. A swampy meadow in each valley corresponds in position to Lake Louise, and these meadows may represent filled-in lake basins.

Of the very many lakes of the Lake Louise type to be found in these mountains we shall only discuss one that was seen near

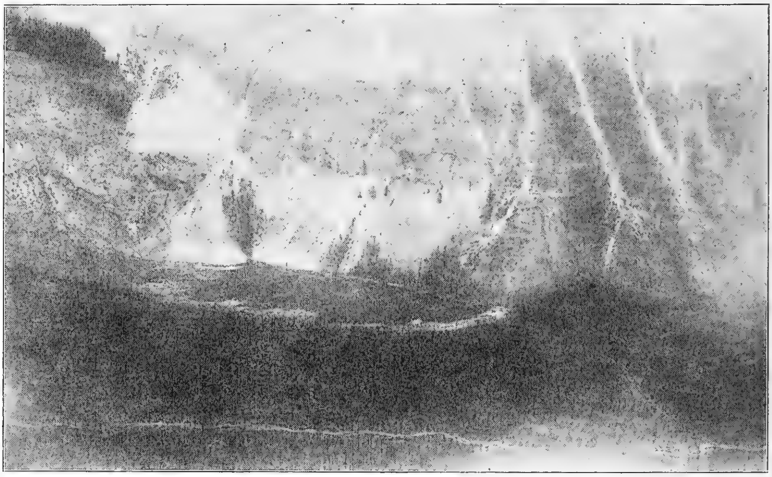


FIG. 4.—Lake near Mt. Assiniboine showing the dam.

the continental watershed in about latitude 51° N. at the base of Mt. Assiniboine, a mountain about 12,000 feet in altitude. The lake was small (Fig. 4), probably one third of a mile long, and occupied the opening of a tributary valley to a stream of moderate size. Owing to distance from the base of supplies in this wild region, there was no time to make an examination of the ridge damming this lake, but it was undoubtedly of drift as was indicated by an abundant forest growth upon it. The shape of this lake, the position of the outlet, and the course of the stream deflected by the drift ridge, are clearly shown in the photograph. This lake is typical of this mode of formation.

A study of many cases showed that a certain ratio between the confluent valleys is necessary to the existence of this kind of lake basin. If the confluent valleys are nearly equal in size, thus showing that the glaciers formerly occupying them were probably of the same dimensions, the drift ridge projects as a long tongue between the two valleys and no basin is formed. If the ratio between the confluent valleys is about three to one or more, the drift ridge is thrown across the mouth of the lesser

FIG. 5.—Lake Louise from the upper end showing the dam.

valley and a lake basin is formed. If, however, the ratio is exceedingly great, the lake basin will either be small, or totally lacking, and will be farther within the lesser valley, as though the lesser glacier had been set back by the great volume of the main ice current.

Many lake basins of this type have been entirely filled in by deposits of glacial streams and the growth of sphagnum mosses or forests which have made peat swamps or flat meadows where a lake basin formerly was.

So constant is this type of formation, that, upon seeing the ratio between certain mountain valleys, the existence and location of such lakes may be predicted with almost invariable success before the lake has been actually seen. The valley of the Little Fork of the Saskatchewan, which is about thirty miles long, has five streams from the west tributary to the main stream, and every valley has a long drift ridge on the upstream side thrown across the openings of the lesser valleys, resulting in the formation of three lakes and two swamps.

The outline of these drift ridges when looked at from a distance and at right angles to them is quite constant in character. Starting with the rock buttress where the formation commences, the drift is at first very steep and clings to the slopes of the rock. As it continues downward, the slope rapidly decreases in a graceful curve till it approaches an angle of about ten degrees. This slope continues through a great part of its length, only to increase again just before the ridge vanishes as a topographic feature. This curve is represented in almost every one of the many examples observed, and, like the outline of drumlins, may be a mathematical curve depending on the physical nature of ice. In general the outlines of these ridges are smooth like a drumlin or tail formation, and not like a terminal or lateral moraine.

A number of sections were found where streams have cut down through the drift and exposed sections from a few feet up to two or even three hundred feet. In all such cases the formation of the ridges was found to be a regular till without internal arrangement.

The horizontal projection of these ridges is slightly curved, and remarkably similar to what would be the lines of medial moraines on confluent glaciers from such valleys. Moreover these curves are assumed regardless of the lesser topographic forms and thus give another proof that they are not moraines.

To summarize the characteristics of these drift ridges, we have the following:

1. Throughout the valleys of the region under discussion,

and by implication a much more extended area, a certain kind of drift ridge is more or less evident wherever a small valley joins a larger one.

2. These ridges are always found between the confluent streams, are crossed by the lesser stream, and are nearly parallel to the larger valley.

3. They sweep out into the main valley or across the mouth

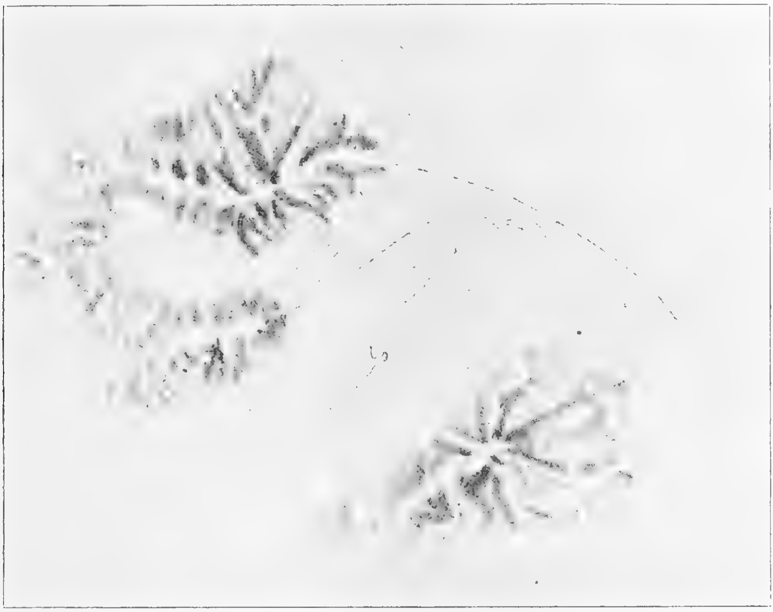


FIG. 6.—Drawing to show probable flow of ice currents from Lake Louise valley.

of the lesser one somewhat proportionally to the probable former dimensions of the glaciers occupying them.

4. They are of unstratified drift, whose upper ends rest against a rock buttress between the confluent valleys.

5. They have a constant characteristic curve of outline, and of horizontal projection, the latter corresponding to what would be the lines of medial moraines on uniting glaciers from such confluent valleys.

6. They are not sharp crested, but are evidently a subglacial

formation and their direction is not, like terminal or lateral moraines, influenced by minor topographic features.

From the foregoing it seems evident that these drift ridges are a subglacial formation disposed under the ice along the same lines as medial moraines would have had on the glacier surface, and that they are a kind of crag and tail formation resulting from the union of two glaciers. The fact that a rock buttress is the initial point of these drift ridges, shows that they were not the result of a short action at the close of the ice invasion. The change of all the preglacial V-shaped valleys to the present U-shaped form was accomplished by a great amount of erosion and transportation of débris. The rock ridges which commence and probably underlie the drift ridges are portions of the old V-shaped valleys which by their position have been preserved. They represent lines of protection from severe erosive action, and it is therefore necessary that the rock should be preserved along the same line in which the drift has been deposited. These lake basins are therefore possibly in many cases rock basins, but made much deeper by an overlying drift formation.

It remains to inquire why the glaciers from the tributary valleys did not cut out channels of even gradient, instead of leaving these basins. Thus the bottom of Lake Louise is 230 feet below the very lowest part of its dam, and the lower surface of its glacier must have ascended this slope upon entering the Bow Valley. A study of existing glaciers shows that a tributary is always narrower after confluence with a larger glacier as a result of the more rapid movement of the ice current. It is probable that this contraction takes place in the vertical dimensions as well as the horizontal, and thus causes the under surface to ascend, while of course the upper maintains its level.

WALTER D. WILCOX.

THE PIRACY OF THE YELLOWSTONE

EVER since the Grand Canyon of the Yellowstone was introduced to the general public, it has enjoyed a well-deserved fame for its grandeur and for the unrivaled beauty of its coloring. To the physiographer it has stood as a type preëminent of a very young river valley in the trench stage of development. All who have seen it have been profoundly impressed by it, and by many it is considered the most satisfying object of beauty in the region. It is now possible to introduce this already famous canyon in a new light, as the scene of one of the greatest acts of piracy on record.

The Yellowstone Lake, with an altitude of 7741 feet A. T., lies in a depression in the southeastern part of the great rhyolite plateau of the Yellowstone National Park. On the east of the lake the land rises rapidly to the high crests of the Absaroka range. On the north and west, and for the most part on the south, the land rises to the general level of the plateau, eight hundred to a thousand feet above the lake. North and south of the lake, and fringing the west shore, are considerable areas of flat land, not far above the present lake level and plainly lacustrine in origin.

The long southeast arm of the lake is seen to be the lower end of a magnificent mountain valley, here submerged. Beyond the lake the valley extends over thirty miles to the southeast, past the limits of the Park, up into the heart of the Absarokas. The upper Yellowstone River occupies this broad vale, at present wandering on a gradient which compels it to constant deposition, the flat bottom of aggraded material averaging over a mile in width for twenty miles southeast of the lake. This valley is manifestly very old, and it has its counterpart in the Lamar Valley in the northeastern part of the Park. It has been shown[1]

[1] ARNOLD HAGUE: The Age of the Igneous Rocks of the Yellowstone National Park, Am. Jour. Sci., 1896, I, p. 454.

that both these valleys were old and well developed before the rhyolites were poured out to form the Park plateau in Pliocene time. The lower courses of both these valleys are masked by the rhyolite flows, and the lake depression itself may be suspected to be a great mountain valley obstructed by lava flows.

The divide west of the lake lies on the flat-topped rhyolite plateau, and at various places there are cols of significant shape and altitude. Plainly some of them have been lines of drainage, showing that at some time water has flowed across the divide, making well-defined valleys. The stage road from the Upper Geyser Basin to the "Thumb," as the west arm of the lake is locally called, passes through one of these notches at the continental divide east of de Lacy Creek. It is rather a narrow valley, with walls perhaps a hundred feet high, cut right across the crest of the divide, yet flat-bottomed and at present marshy and undrained.

It is believed that this whole region has been covered with ice moving west from the Absarokas and north from the Tetons, and it may easily be supposed that in the unequal recession of the ice margin, obstructed drainage would give rise to overflow to the west, establishing channels that would be abandoned on a further recession of the ice. But there is one such channel which gives evidence of very long use even after the ice had left the plateau. This is a "windgap" between Overlook and Channel mountains at *D* in the map, page 263. Here a canyon with walls several hundred feet high cuts across the present divide, down almost to the contour of 7900 feet. Yet this surprising notch is poorly drained, puny streams starting from the marshy col and flowing to opposite oceans. The eastern one is an unnamed branch of Grouse Creek, the one to the west, called Outlet Creek, leads into the Heart Lake basin and so south to the Snake River. This notch has been recognized as a former outlet of the lake, and the fact is well known that the lake was once at this altitude, about one hundred and sixty feet above its present level. Lacustrine deposits are recorded on the United

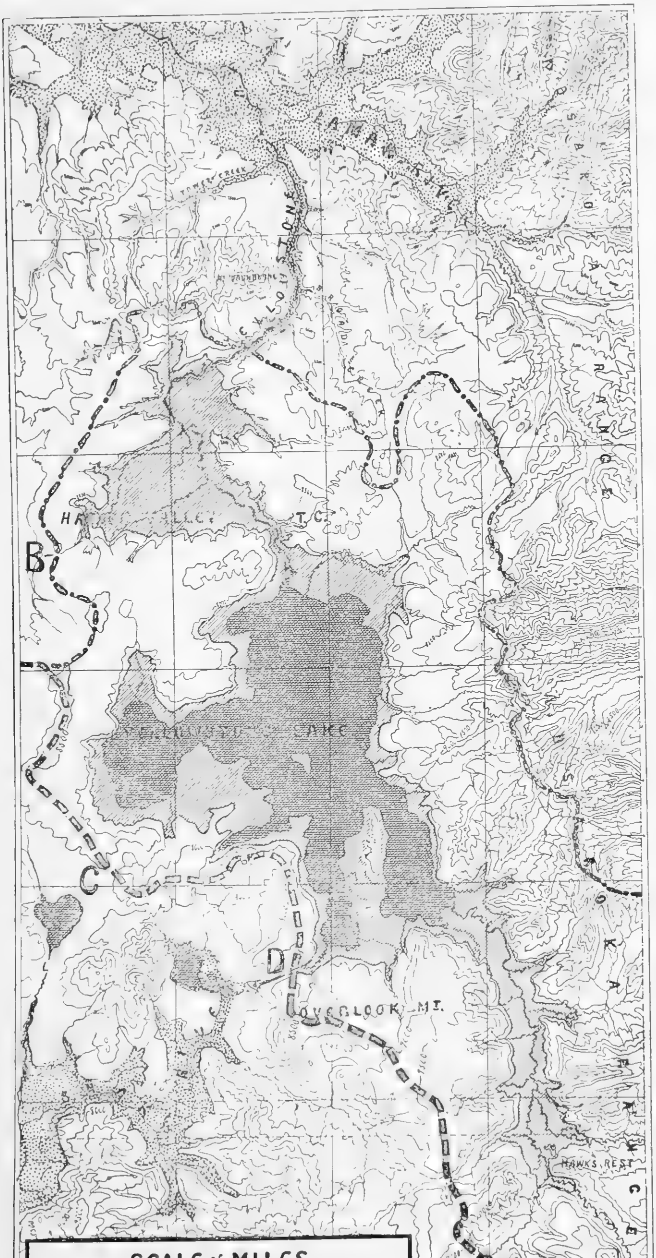


FIG. 1. Map of the eastern part of the Yellowstone National Park. The heavy dotted line *C D* is the present continental divide, the lighter line *B A* the ancient divide. The heavy hachured areas are present lakes, light hachured area is the ancient lake.

States Geological Survey maps,[1] practically up to the 7900-foot contour, all round the lake, and at its foot, to a point four miles below the present lake outlet, at Thistle Creek Canyon, marked *T. C.* on the map, p. 263. At this level also are found terraces, old sea cliffs and beaches, and while other shore phenomena are found at lower levels, as, for example, at the sixty-foot level, yet in some respects the most strongly marked records are at the higher level.

Through the Thistle Creek narrows to the north, the country flattens down into the Hayden Valley—a triangular depression in the plateau, ten miles east and west by seven or eight miles north and south. The surface of this depression is covered largely with moraine deposits of glacial drift, and all round this valley, particularly in the drift, the hills show a significant profile, which, immediately below the Thistle Creek Canyon, is undoubtedly terrace and sea cliff. On the upper courses of Trout Creek, and across the river, east of Crater Hills, similar profiles are seen. The central portion of Hayden Valley is a very flat plain, extending along the two streams, Alum and Trout Creeks. These two streams are wandering on a very low gradient, Trout Creek showing as beautiful an example of oxbows on a small scale as may be found anywhere, and in its wandering, its valley walls show stratified clays, the fresh-cut bank in one place near the roadway standing at a height of over thirty feet against the stream (Fig. 2, *A*, *B*).

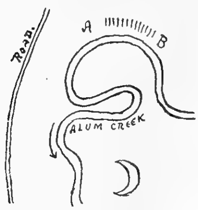


FIG. 2.

At the Grand Canyon the strongest impression one gets is that the canyon is extremely young, that the river is still actively corrading at bottom, and the walls all along are actively sloughing, by every process of degradation. Yet this impression of youth has its greatest emphasis, only when seen from the east flank of Mt. Washburne. Here, at an elevation of about two thousand feet above the plateau, the whole eighteen miles of canyon is in view, from the Falls to Junction Butte, dwarfed now

[1] Yellowstone National Park Folio, U. S. Geol. Surv., Washington, 1896.

by distance into a simple roadside ditch. With this view, it is easy to see that the canyon is not all the same age. The north half of it is distinctly older than the south or upper half. In the north half the shoulders are markedly rounded, the walls less steep, the stream at bottom has long ago found an axial equilibrium with the material it has to handle, and is not deepening or widening its bed in any striking way. It is a surprise to notice, too, that Broad Creek, which empties into the Yellowstone River just at the east foot of Mt. Washburne, has a canyon every whit as wide, as deep, and with shoulders as rounded as has the main canyon at this point.

One cannot help wondering why the Yellowstone Canyon is so young only above this point; why the deep stratified clays in Hayden Valley; why the terrace and cliffs at the high level in Hayden Valley. Why did the Yellowstone Lake abandon a good outlet at Overlook Mountain, and flow off to the north? The explanation may be read from the correlation of the available data as follows.

The Yellowstone Canyon for five miles or so below the falls is extremely young, the occupation by the river representing only a fraction of postglacial time. On the recession of the ice from the region, the plateau of rhyolite stretched untouched by the river action, from the south base of Mt. Washburne southeast across the site of the present canyon, at the general plateau level of about eight thousand feet. There was no canyon, and no Yellowstone River there. The two depressions in the plateau, Hayden Valley, and the present lake basin, if they existed in preglacial time, outflowed by some other route, at present unknown. On the recession of the ice from the region, these basins overflowed to the west, over available cols. Possibilities of such drainage lines, besides the one mentioned on the road to the "Thumb," may be suspected at *A*, *B*, *C*, and *D*, on the map, Fig. 1. But the one which established itself for greatest permanence was the one described at Overlook Mountain.

Now taking the topographic map and supplying a shore line for a lake outflowing at this channel, the surprising fact is shown

that such a lake not only pushes itself into the great valley over sixteen miles to the southeast, but it goes on thru the narrows at Thistle Creek, on the very level of the terrace and sea cliff noted. It covers all the Hayden Valley, with the exception of the very peaks of Crater Hills, and extends on past the falls and the Canyon Hotel to Inspiration Point, thus making a great twin lake extending over fifty-one miles from Inspiration Point on the north to Hawk's Rest far down into the Absarokas on the southeast. This greater lake is shown in the map by the lighter shaded area. The darker shading showing the area of the present lake.

The only assumption necessary in this reconstruction, is the absence of any considerable crustal deformation in postglacial time, and so far as known there is no evidence of any appreciable change of this kind in the area during this time.

Let us look now at the character of the Grand Canyon as it appears among its neighbors. The dominant topographic feature of the northeast part of the park is the great Lamar Valley. It is over two thousand feet deep, and its walls have receded under the tooth of time until a broad and generous vale a mile and more in width at bottom extends for twenty-five miles above the point of its confluence with the Yellowstone River. This vale was old in the Pliocene. It was deep and of generous size before the rhyolites and basalts were poured out to mask the old drainage and make the plateau in which the Yellowstone Lake and Canyon now lie. Once see this great valley and the impression is inevitable that the Yellowstone Canyon is a very late comer. Moreover, as a canyon it is not of much more importance than its neighbor of Tower Creek on the west. In short, the Yellowstone Canyon, from Junction Butte back to the east flank of Mt. Washburne, is not the work of the Yellowstone River at all, but was made by Broad Creek, then a small tributary of the Lamar, of no more consequence than Tower Creek, which joined it from the west. Its canyon may have been begun in preglacial time, but long after the general icesheet had left the region it remained an obscure stream, slowly

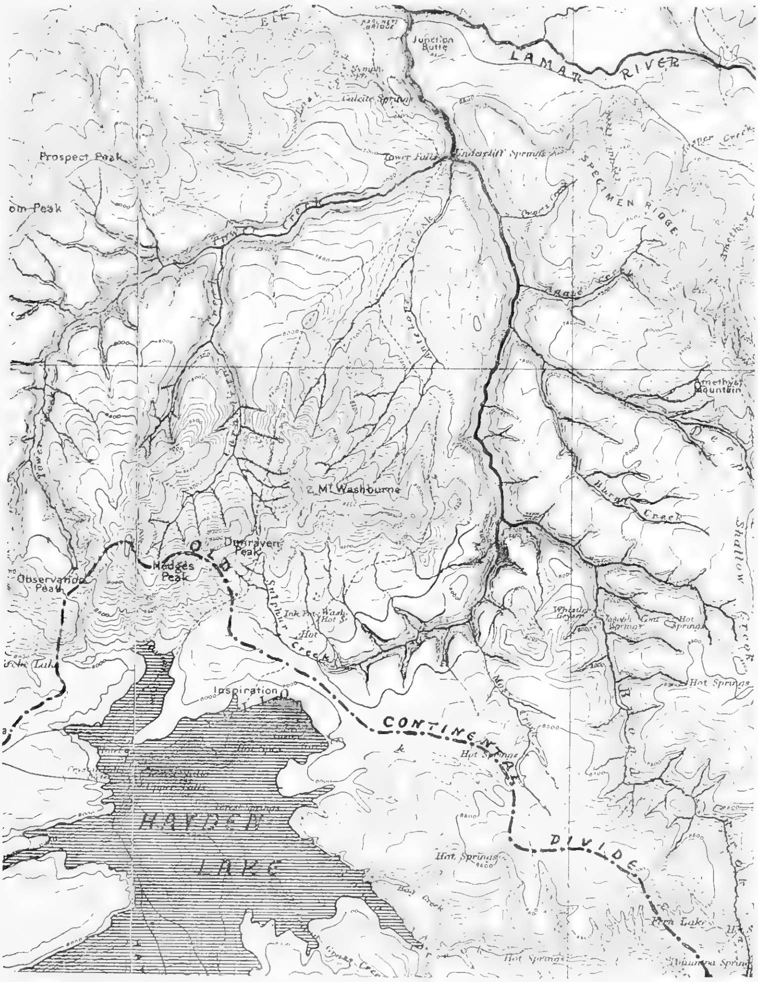


FIG. 3. Map of the scene of the piracy, showing relative size of the canyons of Tower Creek and Broad Creek. The contours of Broad Creek Canyon are supplied in place of the upper half of the present Yellowstone Canyon.

pushing its growing gorge back into the rhyolite of the plateau.

In Fig. 3 the site of the future Grand Canyon is represented, the contours being copied from the U. S. Geological Survey topographic map, with the exception that south from the mouth of the present Broad Creek the contours of Broad Creek itself are supplied, in the line of drainage of Sulfur Creek. The col between the Sulfur Creek gorge and the greater lake lay about two miles north of Inspiration Point in the old Continental divide. Yet the Sulfur Creek pirate was a long time eating thru this two miles or so of barrier. And all this while—a good fraction of postglacial time—the great lake was giving its water thru the Overlook Mountain channel to the Snake River, and the beaches, terraces, and sea cliffs were building at the contour of 7900 feet—about 160 feet above the present lake level. In the Hayden Valley part of the lake, similar beach records were making, and the stratified clays were being deposited off-shore.

The rate of advance thru the col by the Sulfur Creek pirate would depend upon three factors, the volume and gradient of the stream, and the nature of the rhyolite. The volume of water was not large, being only the drainage from the south flank of Mt. Washburne and the east flank of Dunraven Peak. The gradient was high, about 1500 feet, in the Sulfur Creek branch alone, while the rhyolite in the path of the canyon was in admirable condition for easy working.

The rhyolite, on first cooling from its flow, was hard and firm of texture, the obsidian or volcanic glass being one phase of it, usually found at the surface. In deeper levels it may have been as hard and crystalline as basalt; but the hot vapors from below have attacked the firm rock and in many places totally changed its character, making the felspars over into kaolin and leaving the once firm lava a crumbling mass, almost like slaked lime. Yet this solfataric action has not been universal. It has worked very effectively in certain areas, while in other places the solid rhyolite has wholly escaped the decomposing action. Were this not so, the canyon would long ago have advanced clear to the present lake.

The trend of physiographic history in the region was suddenly changed when the col was cut thru by the advancing canyon. The water of the lake began to flow out to the north, the increased volume very greatly hastening the deepening and widening of the trench. The lake level was rapidly lowered, the Overlook Mountain outlet was suddenly abandoned, and with this change the continental divide was transferred to its present position south of the lake. The lowering of the lake level was extremely rapid for a hundred feet, while the outlet was cutting in the decomposed rhyolite merely. In the hundred feet of rapid lowering but slight traces of shore action on the lake could be expected. But this rapid lowering was checked when the river reached the 7800-foot contour, for it came upon a wall of firm, undecomposed rhyolite standing squarely across its path — the site of the present Great Falls — and the river settled down to the task of sawing this barrier in two. It is still at the task, with nearly a quarter of its work yet to do. This barrier is only about a hundred feet thick, and is very plainly marked in the brow of the canyon wall, forming a narrow gateway thru which the water rushes. The inner walls of this gateway are very precipitous, as may be seen in the familiar view of the Great Falls. Immediately above and below this gateway the canyon walls fall away to a wide V-shape in section. The plan, Fig. 4, shows the relation of the barrier to this fall, and how the canyon is narrowed to the precipitous gateway in the barrier. As seen from the down-stream side, this barrier is evidently cut down a little over half its height, and one may easily conjecture that this fall, which is now 312 feet high, must have earlier been much higher, perhaps even 700 feet. The present brow of the fall is near the up-stream face of the barrier, and standing at the brow one may see that the firm rock of the barrier projects at the bottom on the east side of the stream, as a

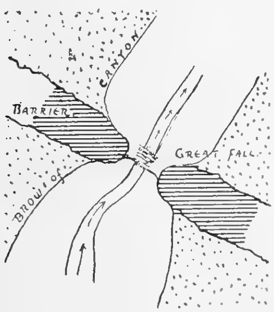


FIG. 4.—Diagram of the barrier at the great fall.

shelving ledge upon which the water is ceaselessly pounding, as shown in longitudinal section in Fig. 5. So this fall may be said to be showing signs of old age—that is, the rapids phase of development has already begun.

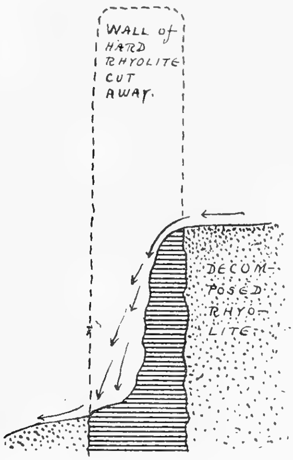


FIG. 5.—Longitudinal diagrammatic section of the great fall.

With the lake outlet approaching this barrier at the contour of 7800 feet a current was formed at the Thistle Creek narrows, and two separate lakes resulted, with a short river between. The lower lake, covering Hayden Valley we may provisionally call Hayden Lake. The river at the narrows had glacial drift only to work on and was competent to cut this out widely as Hayden Lake level followed the lowering brow of the falls.

The problem was made more complex when the river discovered another wall of firm rhyolite at the site of the Upper Fall. This wall is much thicker than the lower one, and the process of cutting is proportionally slower. It was the lowering of this barrier which determined the lowering of Hayden Lake level. When the wall was cut somewhat below the 7700-foot contour, Hayden Lake was drained, and this has only very recently been accomplished, as is shown by the flat and sinuous course of Trout Creek.

The wearing down of the barrier at the Upper Fall has always lagged behind that of the lower. It could not be touched at all, until the lower barrier was reduced below its level, and the height of the Upper Fall has always been limited at its lower level, by the brow of the Lower Fall. The Upper Fall has increased in height almost uniformly with the decrease in height of the Lower Fall, and it is plain to be seen, that when the Lower Fall has finally sawed thru its barrier, the river will carry the canyon gradient back to the Upper Fall which will then be perhaps four hundred feet high.

With the lowering of these two barriers, other barriers were uncovered in the path of the stream above. The most important of these is a ridge of firm rhyolite in the bottom of the Thistle Creek narrows. This became a large factor in the history of the Yellowstone Lake, when in the cutting of the canyon at this point, this firm rhyolite was reached, at a level about sixty feet above the present lake. The lake level since then has waited on the lowering of this one barrier. It is the only barrier which now determines the lake level, altho it seems plausible that in earlier stages, a barrier at Mud Geyser, and perhaps even the Upper Fall barrier, were agents also in maintaining the lake at the sixty-foot terrace, the action on each barrier being much deferred by the lack of gradient due to the former higher elevation of these lower barriers.

This is the postglacial history of Yellowstone Lake and Canyon as it may be read from the data in hand. The whole great lake, with its drainage basin of about fifteen hundred square miles, was captured by the little Sulfur Creek canyon, taken bodily from the Snake River and the Pacific slope, and added to the Lamar River and the Atlantic slope. And the volume of water in the captive stream was so great as to dominate the lower valley of the Lamar, and reduce that older stream to the rank of a minor tributary.

John Paul Goode.

University of Chicago.

THE FAUNA OF THE DEVONIAN FORMATION AT MILWAUKEE, WISCONSIN

The best, and until recently, the only known area of Devonian rocks in Wisconsin lies immediately north of Milwaukee and furnishes the Milwaukee hydraulic cement of commerce. This rock, in the localities where it is exposed, is a limestone, rich in magnesia, alumina, iron and silica. The best known exposure is in the valley of the Milwaukee River, about half a mile north of the present city limits. At this point many acres of the rock are accessible, forming the bed of the river, and stretching away on either side under alluvial and drift deposits, the latter of which constantly increase in thickness with the distance from the river. The formation is here about twenty five feet in thickness. Its surface may be thirty feet above the level of the lake, which lies a mile and a half to the east. There is a slight dip towards the southeast. The formation rests upon a dark, porous limestone supposed to be of Lower Helderberg age, without fossils. Three miles further north, at the edge of Lake Michigan, is an outcrop which rises slightly above the water level, and is about twenty feet thick. A shaft sunk at this place discloses layers corresponding to those of the lower twenty feet of the quarry on the river. Five miles north of the latter and about three miles further west there is a third exposure in a railway cut, at a considerable height above the river which flows near by; but the deep drift in the neighborhood of the cut has prevented any determination of the extent of the formation in this locality.

Within the past five years it has been found necessary to make additional provision for the city's water supply. In carrying out this provision a shaft was sunk to a depth of one hundred and thirty feet at the edge of the beach at the head of North Avenue, and from the bottom of this shaft a tunnel was bored extending out thirty-two hundred feet under the lake. As a preliminary to this undertaking test bores were made at a num-

ber of points. One of these, at a point very near the place where the shaft was finally sunk, revealed the following section, as shown by the records of the City Engineer's office. At the depth of forty two feet below water level, black shale was found, underlying strata of sand, gravel, and red and blue clay ; at fifty seven feet, "soapstone;" at ninety seven feet, cement rock; at one hundred and seven feet, "soapstone" again; at one hundred and thirty-eight feet, "brownstone and lime rock." The "brownstone and lime rock" was not penetrated to any depth and it is not possible, perhaps, to assert positively what it was ; but it is believed to be the same as the Lower Helderberg rock underlying the cement rock on the river.

The material taken from the new intake shaft and tunnel was dumped indiscriminately upon the beach. It has since been spread out, covered with soil, planted with grass and trees and made into a park. It was impossible, for the most part, to sort out the different components of the mass, or to determine except in a general way their original order of superposition. Cement rock and "soapstone" were mingled with each other and are alike disintegrating and turning to clay. The "soapstone" is a lumpy, nodular shale of a greenish-gray color, soft, when wet, hardening into something very like rock when dry, and turning very rapidly to clay under exposure to the rain and air. It strongly resembles some layers of the cement quarry rock, whose lowest and highest layers possess much the same qualities. Portions of the soapstone carry fossils in an excellent state of preservation, of the same species, for the most part, as those found at the quarry on the river. Mixed in with the "soapstone" are very hard layers, from one to four inches in thickness, largely composed of shells of *Chonetes scitulus* Hall, of a gibbous form, associated with *Tentaculites bellulus* Hall. The same form of *Chonetes* is also found amid the softer material in the dump and in the lower division of the quarry. The *Tentaculites* is also found at the cement quarry, but not so abundantly. A distinctly flatter variety of the same species of *Chonetes* is found in other portions of the "soapstone," and in the upper layers of the quarry.

Finely preserved shells of *Spirifer euryteines* Owen, *S. asper* Hall, and *Atrypa reticularis* L., the latter with coarse plications, are found in the "soapstone" and in the upper layers at the quarry. Other portions of the "soapstone" are almost, or wholly, devoid of fossils, and in this they resemble some of the softer layers near the bottom of the quarry.

In the mass dumped on the beach were found some large stones, having the appearance of bowlders, composed of hard rock similar in color to the harder cement rock, but traversed by very hard white seams of a siliceous character. These seams are full of fossils, most of which are also found at the quarry. Such are *Chonetes scitulus* Hall, of the gibbous variety, *Spirifer subvaricosus* H. & Wh., *Palaeoneilo fecunda* Hall, and many others. Associated with these, however, are a number of gastropods, which give a distinctive character to the fauna of these seams; gastropods, with the exception of *Platyceras*, being very rare at the quarry. Among the gastropods of the white seams are *Bellerophon* near *pelops* Hall, and species of Pleurotomaria, Cyclonema and Loxonema.

The black shale, mentioned above as the first rock formation penetrated by the intake shaft, is quite distinct from the other materials dumped on the beach. Pieces of it exhibit glacial scratches. Its only fossils are two or three species of *Lingula*. Certain layers are firm and smooth-grained; others are extremely fissile, splitting into thin, rough laminae. There is also a greenish shale, whose exact place in the series is not ascertainable, also carrying species of Lingula. These shales are not found anywhere else in place in the state, though small rounded pieces are not uncommon in the drift. They seem to have given way everywhere else under the erosive action of the glaciers.

The rock at the cement quarry on the river comprises two main subdivisions distinguished, to some extent, by differences in their fossils, but still more noticeably by the different states of preservation in which their fossils are found. The lower subdivision is twenty-one feet in thickness. Fossils are abundant in this division, but principally in the form of casts and

impressions. Almost the only ones which are well preserved are specimens of *Lingula*, *Orbiculoidea* and *Conularia;* the plates, scales and teeth of fishes; and some plant remains in carbonized form. At the top of this section is a very hard layer about six feet in thickness, containing cavities lined with crystals of calcite and pyrite. This layer is very rich in fossils, very few forms being absent from it which are found in any part of the quarry; and it is especially distinguished by the multitude of its cephalopod and fish remains. The layers below this one are softer, some of them very soft indeed, and are on the whole less rich in fossils; but the surfaces of some of the lower layers are covered with pyritized shells of brachiopods, mainly *Chonetes scitulus* Hall, of the gibbous form, and *Delthyris consobrina* D'Orb.

The upper subdivision comprises the upper four feet of the quarry. Its surface has been smoothed by glacial action. Most of its fossils are found as casts in the section below, but here the shells are often preserved. Much of the rock of this division is of a lumpy, nodular character, and suffers rapid disintegration under atmospheric influences, the fossils weathering out.

These two sections, at the lake and at the river, are not precisely alike but are easily correlated with each other. The entire series of Milwaukee Devonian rocks may therefore be conveniently subdivided as follows, the section at the water tunnel being designated A, and the section at the cement quarries B.

A 4. The Lingula-bearing shales.

A 3. That portion of the "soapstone" carrying shells of *Spirifer euryteines* Owen, *S. asper* Hall, and *Atrypa reticularis* L., and the flat variety of *Chonetes scitulus* Hall; being the upper "soapstone" of the City Engineer's section.

A 2. This includes the thin hard layers so rich in specimens of the gibbous variety of *Chonetes scitulus* Hall, and *Tentaculites bellulus* Hall. It also includes portions of "soapstone," probably the lower "soapstone" of the City Engineer's section, containing the same variety of *C. scitulus* Hall, and *Conularia*. Its relations seem to be with subdivision B 1 of the quarry rock.

A 1. This consists of the thin white seams, whose relations are not definitely known.

B 2. The upper four feet of the quarry rock, corresponding with A 3.

B 1. The lower twenty-one feet of the quarry rock, including the very hard six-foot layer and several softer and less fossiliferous ones. This corresponds with A 2.

Very likely subdivision B 1, at the cement quarry, could be still further subdivided, the exceedingly hard layer at the top being especially worthy of a place by itself. It is sufficient, however, at present to say that this layer probably carries all the fossils of the layers below it except the plants — which come from further down — most of those above, and in addition a large number of fossils peculiar to itself. Among the latter are most of the fishes, most of the cephalopods, a few brachiopods and many pelecypods.

In the following table an attempt has been made to bring together the fossils of the several subdivisions for purposes of comparison. The lists are not exhaustive. Even at the cement quarry, which has been the most thoroughly examined, new species are occasionally found. The faunas of the shale and "soapstone" are less perfectly known, owing to the limited opportunity afforded for their study. Yet the formation has already furnished in the neighborhood of two hundred species, a remarkably rich collection from so limited a territory.

The determinations of species are in some cases provisional. The specimens of *Chonetes* and *Spirifer* have been submitted to Professor R. P. Whitfield and Mr. Charles Schuchert. The fish remains have been identified by Dr. C. R. Eastman and the crinoids by Mr. Stuart Weller. In other instances some of the names may have to be changed. Some of the species are new and have not yet received names.

It will be noticed that some species which are mentioned in the *Geology of Wisconsin* as coming from this formation are not contained in this list. Among them are *Chonetes coronatus* Conrad; *Productella spinulicosta* Hall and *Trematospira hirsuta*

Hall, all of which were probably determined from imperfect casts, or may have been taken from erratic blocks wrongly supposed to have been derived from this formation. Others, like *Spirifer granuliferus* Hall, *S. audaculus* Conrad, *S. angustus* Hall, and *S. euryteines*, var. *fornaculus* Hall, were probably mistaken identifications, justified at the time, but based upon casts of *Spirifer euryteines* Owen, which here exhibits great variations of form. Shells of the last named species are rarely found at the quarry, and only in one or two places, not in the rock but in the soil above composed of disintegrated rock. They are quite abundant in the upper "soapstone" from the intake. It is not probable that any had been unearthed at the time of the publication of the *Geology of Wisconsin*. They are distinguished by clearly marked lines of fine striation.

The writers have not attempted the correlation of the Milwaukee fauna with the faunas of other localities, but leave that interesting task to more competent hands. The Spirifers of the list, however (*S. iowaensis* Owen = *S. pennatus* Owen; *S. asper* Hall; *S. euryteines* Owen = *S. parryanus* Hall = *S. capax* Hall; and *S. subvaricosus* H. & Wh.) show an obvious relation to certain Devonian faunas of Iowa. It is proper to state that the shell here identified as *S. subvaricosus* H. & Wh. was by Mr. Schuchert considered to be a primitive form of *S. bimesialis* H., another Iowa species. Professor Whitfield, however, considers the identification as *S. subvaricosus* to be correct. Specimens of the shell from B 2, in which the beak has been ground down, seem to show a median septum. So do the casts in B. The latter, however, do not generally show the strong plication of fold and sinus, and such have been identified as *Delthyris consobrina*, D'Orb. (= *S. ziczac* Hall.) There is in the list a little *Rhynchonella*, identified as *R. contracta*, var. *saxatilis* Hall, which, if properly named, belongs also to the Rockford and High Point faunas. The Milwaukee specimens of *Schizophoria striatula* Schl. (= *Orthis impressa* Hall) are a form with a wide and not very deep sinus. Occasional forms are found resembling *Schizophoria tulliensis* Vanuxem, and *S. macfarlani* Meek.

A partial correlation of the fish remains has been furnished us by Professor Eastman. It is as follows:

Dinichthys pustulosus, Eastman — Hamilton Group of Iowa, Illinois and New York; Upper Devonian of Iowa.

D. tuberculatus, Newberry — Chemung Group of Pennsylvania; Upper Devonian of Belgium.

Ptyctodus calceolus, N. & W.—Hamilton Group of Iowa, Illinois, Missouri, Manitoba; Upper Devonian of Iowa.

Heteracanthus uddeni, Lindahl — Hamilton Group, Buffalo, Ia.

Onychodus sigmoides, Newberry — Corniferous Group of Ohio and New York; Chemung Group, Delaware county, N. Y.

Acantholepis fragilis, Newberry — Corniferous of Ohio & New York.

Sphenophorus, sp. — Chemung Group of Pennsylvania (*S. lilleyi* Newb.)

Note.—In the following tables the position of the various species in the different subdivisions is indicated according to their relative abundance by the letter A, abundant; C, common; O, occasional; R, rare.

FAUNA OF THE MILWAUKEE DEVONIAN FORMATION

	A_4	A_3	A_2	A_1	B_2	B_1
PISCES						
Acantholepis fragilis Newb. (= *A. pustulosa* Newb.)					Occasional small fish remains	R
Cladodus sp.						R
Dinichthys pustulosus Eastman						O
D. tuberculatus Newberry						R
D. sp.						R
Heteracanthus politus Newberry						R
H. uddeni Lindahl						R
Onychodus sigmoides Newberry						R
Palaeomylus greenei Newberry						O
Phlyctaenacanthus telleri Eastman						R
Ptyctodus calceolus N. & W.						R
P. ferox Eastman						R
Rhynchodus excavatus Newberry						R
Sphenophorus sp.						R
Titanichthys sp.						R
Scales of fishes, of undetermined species						O
CRUSTACEA						
Echinocaris (= *Ceraliocaris*) sp.						R
Phacops rana Green					C	O
Proëtus sp					R	R
P. sp.				R		
CEPHALOPODA						
Gomphoceras breviposticum Whitfield						O
G. fusiformae Whitfield						O
G., at least ten other species, large and small, including so-called "Horses' Hoofs," all from B_1						
Goniatites sp						R
Gyroceras eryx Hall						C
G., three or four other species						R
Orthoceras, large, like *O. bebryx* Hall						R
O., very slender				R		
O., one or two other species					R	R
PTEROPODA						
Conularia sp.		?	R		R	R
Hyolithes sp.				R	R	R
Tentaculites bellulus Hall			A	A		R
GASTROPODA						
Bellerophon, near *pelops* Hall						
Callonema sp				R		
Cyclonema sp.					R	
Loxonema sp.				R		
Murchisonia sp., minute, preserved in pyrites						R
M. sp., large					R	
Platyceras auriculatum Hall					R	
P. carinatum Hall					R	
P. erectum Hall					R	
P., two other species					R	
Pleurotomaria, two or three species				R		

	A_4	A_3	A_2	A_1	B_2	B_1
PELECYPODA						
Actinopteria sp.				R		
A. sp					R	R
Cimitaria elongata Conrad						R
Clidophorus oblongus Hall						R
Goniophora hamiltonensis Hall						R
Grammysia nodocostata Hall		R				R
G. subarcuata H.						R
G. sp						R
Leda, near *rostellata* Conrad						R
Lyriopecten, near *interradiatus* Hall						R
Modiola precedens Hall						R
Modiomorpha affinis Hall						R
M. alta Conrad						R
M. concentrica Conrad					R	O
M. macilenta Hall						R
M. mytiloides Hall						R
M. ponderosa Hall						R
M. quadrula Hall						R
M. subulata Hall						R
M. subulata var. *chemungensis* Hall						R
Mytilarca umbonata Hall						R
M. (*Plethomytilus*) *oviformis* Conrad						R
Nucula corbuliformis Hall						O
N. randalli Hall						O
Nuculites oblongatus Conrad				R		
Palaeoneilo brevis Hall		R				
P. constricta Conrad				O	O	C
P. elongata Hall						R
P. emarginata Hall				R		R
P. fecunda Hall		O		O	O	O
P. plana? Hall				R		R
P. sp		R				
Paracyclas elliptica Hall				R		
P. tenuis Hall						R
Pterinopecten, near *intermedius* Hall		R				
Sphenotus, near *cuneatus* Conrad						R
S., near *clavulus* Hall						R
Many other species of Pelecypoda, imperfectly preserved in B_1						
BRACHIOPODA						
Athyris fultonensis Swallow		R			A	R
A. sp.					R	
Atrypa hystrix, var. *occidentalis* Hall						O
A. reticularis L		A	O	O	A	A
A. spinosa Hall						R
Camarotoechia near *sappho* Hall						R
C. contracta, var. *saxatilis* Hall		R		R	R	R
Chonetes scitulus Hall—flat variety		O			A	
C. scitulus Hall—gibbous variety			A			C
C. vicinus Castelnau (=*C. deflectus* Hall)						R
Craniella hamiltoniae Hall						R

	A_4	A_3	A_2	A_1	B_2	B_1
Cyrtina curvilineata White					R	
C. hamiltonensis Hall		R			A	R
C. hamiltonensis var. *recta* Hall		R			C	R
Delthyris consobrina D'Orbigny				C		A
Dielasma calvini H. & Wh.					C	
Eunella lincklaeni Hall					O	
Liorhynchus kelloggi Hall						O
L. sp.						R
L. sp.		R				
Lingula complanata Williams	R					
L. maida Hall						R
L. melie Hall	C					
L. spatulata Vanuxem	R					R
L. sp.						R
Lingulella paliformis Hall						R
Orbiculoidea lodiensis Hall		O			O	O
O. lodiensis var. *media* Hall		O			O	O
O. marginalis Whitfield		O			O	O
O. two other species						R
Orthis sp.					R	
Orthothetes chemungensis var. *arctistriata* Hall		O		R	O	O
Pentamerella, two species						R
Pholidostrophia iowaensis Owen		O			A	R
Schizophoria macfarlani Meek					R	
S. striatula Schlotheim		R			A	A
S. tulliensis Vanuxem					R	R
Spirifer asper Hall		C		R	O	O
S., near *Euryteines* Owen		C	R	R	O	A
S. iowaensis Owen					R	O
S. pennatus Atwater					R	R
S. pennatus var. *posterus* Hall						R
S. subvaricosus H. & Wh.				O	A	O
S. sp						O
Stropheodonta demissa Conrad		O	R	R	A	A
S. perplana Conrad		O	R	R	A	A
S. sp					O	O
Terebratula, one or two species					R	
BRYOZOA — including Monticuliporoids						
Aulopora, two species, free growing					O	
A., one or two species on shells of Brachiopods					O	
Fenestella sp.						O
F. sp.						R
F. sp.					R	
Hederella, one or two species on shells of Brachiopods					C	
Hernodia humifusa Hall, on Gomphoceras						R
Reptaria stolonifera Rolle, on Gomphoceras						R
Stictopora, one or two species					A	
Stomatopora sp., on shells of Brachiopods						R
Of Monticuliporoids there are several different genera and species; with simple thin-walled cells; with thick-walled cells; with intermediate mesopores; massive, dendritic, and laminar — In Section A_3 and B_2.						

	A_4	A_2	A_2	A_1	B_2	B_1
ANNELIDA						
Cornulites sp.					R	
Spirorbis, one or two species, on Brachipods					R	R
ECHINODERMATA						
Melocrinus milwaukensis, Weller					R	
M. milwaukensis var. *rotundatus* Weller					R	
M. nodosus Hall					R	
M. nodosus var. *spinosus* Weller		R			R	
M. subglobosus Weller					R	
M. sp.					R	
Pentremitidea filosa Whiteaves					R	
P. milwaukensis Weller					R	
Taxocrinus sp.					R	
Crinoid stems of several sorts					C	
COELENTERATA						
Favosites sp.						R
Heliophyllum halli Ed. & H.						R
Zaphrentis, one or two species						R
SPONGIDA						
Sp. ?						R
PLANTAE						
About a dozen carbonized forms of land plants of several genera; some threadlike, or with threadlike branches; the largest over four feet long and as much as five inches wide; all somewhat flattened; mainly in the softer layers of B_1.						
Also several species of fucoids, in all layers of both sections.						

As we go to press, Dr. C. R. Eastman, furnishes the following note on the fossil fishes mentioned in the foregoing article:

ELASMOBRANCHS

Ptyctodus calceolus N. & W. (Tritors only).

P. ferox East. (Complete dental plates, upper and lower jaws).

Rhynchodus excavatus Newb. (Complete dental plates, upper and lower jaws).

Palaeomylus greenei (Newb.). (Complete dental plates, upper and lower jaws).

Cladodus sp. nov. (Detached teeth).

Heteracanthus politus Newb. (Spines).

H. uddeni Lindahl. (Spines).

"PLACODERMS" (including *Arthrodira*)

Acantholepis fragilis Newb. (=*A. pustulosa* Newb.). Fragmentary spines).

Phlyctaenacanthus telleri Eastm. (Fragmentary spines).

Dinichthys tuberculatus Newb. (Fragments of dermal armor).

D. pustulosus Eastm. (Crania, dorsal and ventral plates; also portions of the dentition).

Large, thin plates belonging to two as yet unknown Dinichthyids, probably *Dinichthys* or possibly akin to *Titanichthys*.

Sphenophorus sp. nov. (Fragments of dermal plates).

CROSSOPTERYGIANS

Onychodus sp. (Clavicle and other plates very suggestive of *O. sigmoides* Newb., but as yet no teeth nor scales, sufficient to prove specific identity).

Several varieties of scales and other fragments.

CHARLES E. MONROE.
EDGAR E. TELLER.

MILWAUKEE, WIS.
February 16, 1899.

THE PETROGRAPHICAL PROVINCE OF ESSEX COUNTY, MASS. IV.

BASIC DIKES

By far the greater part of the dikes of this region are dense black rocks, evidently very basic in character. The majority of these are diabases of various kinds, only a few not belonging to this ever-present family and representing more unusual types. However, these basic dikes have been so far but little investigated, but it will not be amiss to describe the specimens in my possession.

Camptonitic dikes.— Cutting the foyaite of Salem Neck and, according to Sears, the "augite-syenite" of Coney Island in Salem Harbor are dikes of dense, black, finely crystalline rock without phenocrysts, and composed essentially of hornblende, less augite, and plagioclase. These rocks are unlike typical camptonites since there are no large and abundant ferromagnesian phenocrysts, and alumina is rather high. In certain respects they seem to be allied to the proterobases. They are provisionally classed with the camptonites for various reasons, among which may be mentioned their connection with foyaite, certain features of their chemical and mineralogical composition, and their resemblance to camptonitic rocks from localities in Maine, New Hampshire, Vermont, and Norway. It is, by the way, a somewhat remarkable fact that no typical camptonites or monchiquites have yet been observed in the region.

Under the microscope these rocks are holocrystalline, and in fresh specimens have a structure approaching the ophitic, though the colored components are, as a rule, more automorphic than is the case when this structure is typically developed. The following minerals are present: much hornblende, less pyroxene, occasional olivine, plagioclase, a little orthoclase, some magnetite, and rare apatite. Neither biotite nor titanite were seen.

The hornblende forms either stout prismatic crystals or irregular grains. In the latter case it is generally, but not constantly, later than the plagioclase and interstitial to some extent. It is a peculiar yellow-brown, closely similar to the barkevikite of the Norway rocks, as shown by comparison with sections of these. The pleochroism is strong: for the axis nearest *c*, dark yellow-brown; parallel to axis *b*, about the same, nearly parallel to axis *a*, light greenish-yellow. The depth of the color rendered the determination of the axes of elasticity uncertain. The extinction is rather high, about 20 degrees. This hornblende frequently occurs as a primary border about augite and magnetite, as in the hyperitic diorites. The pyroxene, which forms irregular grains or occasionally large porphyritic crystals, is colorless, with sometimes a tinge of green or violet. Olivine is rare, except in one specimen from Coney Island, in large corroded colorless grains. They are usually altered at the borders to a black granular substance, and are occasionally serpentinized. The plagioclase, which occurs in long lath-shaped sections, tabular parallel to *b* (010), as well as in anhedra, is highly twinned. Measurements by Michel-Lévy's method indicate a labradorite with the composition $Ab_3\ An_4$, though some are nearer the andesines. Small colorless interstitial grains with low refractive index are referred to orthoclase.

	I	II	III	IV
SiO_2	46.59	48.98	45.20	48.08
TiO_2	1.41	0.56	0.68	2.57
Al_2O_3	17.55	17.76	17.12	16.95
Fe_2O_3	1.68	2.14	5.98	4.78
FeO	10.46	6.52	6.55	7.60
MnO	.....	.....	.....	trace
MgO	7.76	2.09	5.29	5.51
CaO	10.64	8.36	7.89	7.79
Na_2O	3.31	6.77	4.23	3.37
K_2O	0.72	2.08	2.31	1.42
H_2O (110°)	0.10	.....	.....	.....
H_2O (ignit.)	0.07	4.50	5.35	0.80
P_2O_5	.....	.....	.....	0.63
CO_2	....	0.82	.....	.....
	100.29	100.58	100.60	99.48

I. Camptonite (?). Salem Neck. H. S. Washington anal.

II. "Diorite-Porphyrite." St. Johns, N. B. W. D. Matthew, Trans. N. Y. Acad. Sci., Vol. XIV, p. 213, 1895.

III. Camptonite. Portland, Me. E. C. E. Lord, Amer. Geol., Vol. XXII, p. 344, 1898.

IV. Bronzite-Kersantite. Hovland, Norway. Brögger, op. cit., Vol. III, p. 75.

An analysis of a fresh specimen from a narrow dike cutting foyaite on Salem Neck is given in I. The low titanium oxide accords with the absence of titanite and the character of the pyroxene. It is evident that alumina largely replaces ferric oxide in the ferro-magnesian minerals. This is a feature of barkevikite as shown by Flink's analysis,[1] and some of the hornblendes whose composition has been calculated by Brögger,[2] as well as of the hornblende of Hawes's camptonite.[3]

As was stated above very similar rocks have been observed in New England. For instance, it resembles a specimen from Livermore Falls, near Campton, N. H., for which I am indebted to Professor Pirsson. This, however, does not carry hornblende phenocrysts, and is also like some of the camptonites of Lake Champlain.[4] Hobbs[5] also describes similar rocks as augite-diorite, occurring in connection with the diabase of Medford, Mass. A nearly identical rock is described by W. D. Matthew[6] as occurring in dikes near St. Johns, N. B. The hornblende is also apparently barkevikite, and an analysis of this rock is given in II. Very recently E. C. E. Lord[7] has described a dike of camptonite from Portland, Me., which is closely allied, and the analysis of which is given in III. These two contain considerably more alkalies than those described in this paper. These

[1] DANA, A System of Mineralogy, New York, 1892, p. 403.

[2] BRÖGGER, op. cit., III, p. 110.

[3] LORD, Amer. Geol., Vol. XXII, p. 343, 1898; also, ROSENBUSCH, Elem. Gest-lehre, p. 234, No. 1, 1898.

[4] KEMP and MARSTERS, Bull. U. S. G. S., No. 107, p. 29, 1893.

[5] W. H. HOBBS, Bull. Mus. Comp. Zoöl., Vol. XVI, p. 10, 1888.

[6] W. D. MATTHEW, Trans. N. Y. Acad. Sci., Vol. XIV, p. 210, 1895.

[7] E. C. E. LORD, Amer. Geol., Vol. XXII, p. 342, 1898. *Cf.* KEMP, dikes near Kennebunkport, Me., Amer. Geol., p. 129, 1890.

are all decidedly more acid than the usual camptonites, and carry higher alumina. Chemically they show marked affinity with certain kersantites from Norway described by Brögger,[1] one of his analyses being given in IV.

Vogesitic dikes.— A few dikes were found of a dark rock composed of hornblende, augite, and biotite, but with alkali-feldspar very largely predominating over plagioclase. A little quartz is also apt to be present, which is apparently primary. These rocks then have the mineralogical composition of vogesite or minette, apart from the presence of quartz, and are provisionally put here, since no chemical analysis has yet been made of them.

As an example there may described a dike from Davis Neck, Cape Ann, which is almost black, fine-grained, and compact, and with small shining black phenocrysts of ferro-magnesian minerals. Of these the pyroxene is colorless or very pale green, the hornblende of a light bluish-green, both in irregular grains, and the biotite in thick plates of a light brown color and highly pleochroic. These minerals are not distributed evenly, but occur in streaks in which one or the other predominates. The interstitial groundmass is of colorless granular alkali-feldspar without plagioclase or quartz. A little magnetite is present but no apatite.

Diabase.— Dikes of dense black rock, which may be grouped under this heading, are very abundant. They far outnumber all the other dikes put together, but as is usually the case they are rather monotonous in character, as well as nearly always more or less altered. Shaler's map of Cape Ann will show their abundance, and to his paper[2] the reader is referred for a full discussion of their occurrence, dip and strike, and other features. As regards their relations to the other rocks it may be noted that they cut, and are hence later than, all the other types.

They vary from fine-grained to aphanitic, the usual change in texture from center to border being often seen. In general they are not as coarse-grained as the sheets, dikes, and flows of

[1] BRÖGGER, op. cit., Vol. III, p. 71

[2] SHALER, Ninth Ann. Rep. U. S. G. S., 1889.

similar rock which are met with in such abundance in the Triassic of Connecticut and New Jersey, this being due to their having cooled as much smaller bodies. Amygdaloidal structure is very rare. They may be divided roughly into two main groups, the ophitic and basaltic, though these merge into each other, and frequently the center of a dike is ophitic while its border is basaltic.

The ophitic diabases present the usual features. The feldspar, in stout plates, is chiefly a well-twinned plagioclase, with extinction angles corresponding to a labradorite of about the composition $Ab_1 An_3$. It is often cloudy or epidotized through alteration. A little orthoclase seems to be present. The augite, which is seldom automorphic, is pale violet-gray in thin sections, and is frequently uralitized, often to such an extent that little of the original mineral remains. Magnetite is quite common in large grains, often showing octahedral outlines, and has a strong tendency to stout skeleton growths. An interesting case of this is seen in a dike-cutting rhyolite on Marblehead Neck where the magnetite skeletons assume the form of small stout crosses with thickened ends, or with their ends joined by the sides of a hollow square, the cross in this case forming the diagonals. These growths are analogous to those of leucite in certain leucitites from Montana[1] and Italy.[2] The magnetites are frequently accompanied or surrounded by brown, apparently secondary, biotite, even in the freshest specimens. With this exception neither biotite nor hornblende is to be seen, nor was olivine observed. Apatite is not abundant.

The basaltic diabases are black and aphanitic, without megascopic phenocrysts. They show in thin sections laths of clear labradorite and some crystals of augite in a mixture of augite grains, small labradorite laths and magnetite with considerable light-brown glass base. The magnetite very frequently assumes delicate arborescent forms, branching at right angles, which are very pretty and characteristic. In a small apophysis of the

[1] L. V. PIRSSON, Bearpaw Mountains, Am. Jour. Sci. (4), Vol. II, p. 145, 1896.

[2] H. S. WASHINGTON, Bolsena, JOUR. GEOL., Vol. IV, p. 557, 1896.

ophitic Dike 73, at Bemo's Ledge, Cape Ann, magnetite is wanting and the brown glass abundant. Flow structure is sometimes seen. These varieties closely resemble many normal olivine-free basalts.

	I	II	III	IV	V
SiO_2	47.12	48.75	51.78	51.36	36.85
TiO_2	3.27	0.99	1.41	....	....
Al_2O_3	14.43	17.97	12.79	16.25	15.46
Fe_2O_3	3.33	0.41	3.59	2.14	....
FeO	11.71	13.62	8.25	8.24	17.50
MnO	....	0.91	0.44	0.09	....
MgO	6.05	3.39	7.63	7.97	5.60
CaO	9.63	8.82	10.70	10.27	15.73
Na_2O	2.58	1.63	2.14	1.54	....
K_2O	1.11	2.40	0.39	1.06	....
H_2O (110°)	0.28	....	....	.....	....
H_2O (ignit.)	0.34	0.60	0.63	1.33	....
P_2O_5	....	0.68	0.14	....	....
	99.85	100.17	99.89	100.28	91.14

I. Diabase. Rockport. H. S. Washington anal.

II. Diabase. Medford, Mass. Sweetser anal. Traces of CO_2 and FeS_2. Probably Al_2O_3 too high and MgO too low. Hobbs, Bull. Mus. Comp. Zoöl. XVI, p. 9, 1888.

III. Diabase. West Rock, New Haven, Conn. G. W. Hawes anal. Proc. U. S. Nat. Mus., IV, p. 132, 1882.

IV. Diabase. Watchung Mountain, Orange, N. J. L. G. Eakins anal. Bull. 148 U. S. Geol. Surv., p. 80, 1897.

V. Diabase (?). Marblehead Neck. R. Pearce, Proc. Colo. Sci. Soc., IV, 1893.

For purposes of analysis the freshest specimen was chosen from a dike of ophitic diabase cutting the granite in the large quarry pit at Rockport. It calls for little remark, except that the alumina is rather low and the titanium oxide is high. It resembles analyses of other diabases from Massachusetts, one of which is given (II), but is more basic than the "traps" of Connecticut and New Jersey (III and IV). For purposes of completeness a partial analysis is given (V) of a so-called diabase dike, briefly noticed by R. Pearce, from Marblehead Neck. It is not very satisfactory. The silica is abnormally low, lime high,

as well as iron oxides, and the large loss is difficult to account for, assuming that the analysis is correct. There cannot be enough alkalies to make up the deficiency, and it is probably largely water. The rock is possibly decomposed, since Merrill[1] has shown that diabase loses silica through decomposition. It is also possible that it is a monchiquite.

Labradorite-porphyry.—Closely related to the diabases are a few dikes distinguished by the presence of prominent phenocrysts of plagioclase in a black, fine-grained groundmass. The best example is Shaler's Dike 175, which cuts across the quarry pit at Pigeon Cove. It is eighteen feet in width, with a strike of N. 9° W.[2] The phenocrysts here are very large and automorphic. A similar dike cuts the tinguaite at Pickard's Point, in which the phenocrysts at the center are even larger, attaining diameters of more than six inches; toward the borders they are smaller, and at the contact very small.

The groundmass of these rocks is like that of the diabases, though an ophitic structure is less often developed. It is composed of labradorite, augite, and magnetite, primarily, but in every case is more or less altered, so that secondary hornblende and biotite with chlorite, etc., are present in abundance, and any analysis would be unsatisfactory.

EXTRUSIVE ROCKS

Rhyolite.—The only flow rocks found in Essex county are rhyolites, which occur in large sheets about Lynn, Newbury, Old Town, and Marblehead Neck. The last is the only locality which I have visited. This is not the place to dwell upon the discussions which have taken place as to the origin of these rocks, between Sterry Hunt and his followers, who tried to show that these, as well as all the igneous rocks of the region, were altered sediments, and the other party, headed by Wadsworth and Diller, who finally overthrew this view and proved conclusively that they are typical volcanic flows. For particulars of this discus-

[1] G. P. Merrill, Bull. Am. Geol. Soc., Vol. VII, p. 349, 1896.

[2] Shaler, op. cit., pp. 592, 607.

sion the reader is referred to "The Azoic System," by Whitney and Wadsworth.[1]

These rhyolites are dense, black, aphanitic rocks, with a dull or subvitreous luster and subconchoidal to even fracture. Small, white feldspar phenocrysts are scattered through this black groundmass. A banded or flow-structure is often noticeable, and is especially well brought out on weathered surfaces.

Under the microscope these rocks present a somewhat monotonous appearance. The feldspar phenocrysts are usually quite sharply automorphic, less often fragmentary. Most of these are of orthoclase, or rather soda-orthoclase, while a few show the twinning lamellæ and extinction angles of oligoclase-albite. They are all somewhat decomposed so that optical examination is unsatisfactory.

The groundmass is composed of alkali-feldspar with some finely granular quartz, very small shreds and grains of pale greenish pyroxene and a little magnetite. Glass is present in some specimens, but in the majority of cases it has been devitrified, and its former presence is difficult to determine with certainty. Some of the specimens were apparently primarily holocrystalline. Flow-structure is observed, but is not as marked as one would be led to expect from some of the weathered specimens. These rhyolites, it may be added, are accompanied by ash beds and breccias.

I owe to Mr. Sears a specimen of a dike rock much like these rhyolites, which cuts the diorite on the south shore of Salem harbor, west of Marblehead. It shows flesh-colored feldspar and colorless quartz phenocrysts in an aphanitic groundmass. In thin section it resembles the rhyolites, but is distinguished by the abundance and sharp outlines of the quartz phenocrysts and the presence of numerous spherulites in the devitrified groundmass, which exhibit a black cross between crossed nicols.

[1] Bull. Mus. Comp. Zoöl., Vol. VII, Cambridge, 1884, pp. 331–565. *Cf.* also G. H. Williams, Jour. Geol., Vol. II, p. 24, 1894.

SiO_2	70.64	MgO	0 52
TiO_2	0.90	CaO	1.24
Al_2O_3	15.34	Na_2O	5.23
Fe_2O_3	1.83	K_2O	3.55
FeO	1.10	H_2O (110°)	0.14
MnO	trace	H_2O (ignit.)	0.38
			100.87

Rhyolite. Northeast coast of Marblehead Neck. H. S. Washington anal.

For the analysis a typical specimen was chosen from the northeast coast of Marblehead Neck. As will be seen, these rocks are rather acid, and resemble the quartz-syenite-porphyry more than they do the aplite. The only point to be mentioned here is that soda is considerably higher than potash.

Keratophyr.—The last rock to be described is that by which this region is, perhaps, best known, which Rosenbusch[1] has taken as the type of his bostonites, and which Sears[2] has described as keratophyre. Accepting provisionally Rosenbusch's system of classification the choice of names depends on whether the rock occurs as a dike or a flow. Owing partly to the fact that the exposure is only visible at low tide the relations are somewhat difficult to make out. My observations were confirmatory of the views expressed by Wadsworth[3] and Sears[4] that the rock forms a flow and not a dike, overlying rhyolite and conglomerates. This being so, I think that the name bostonite is not justified in this case, and I prefer to retain Sear's name, keratophyr (rather than trachyte), on account of the large content of anorthoclase, even though this name is in several respects a very bad one.

My specimens come from Boden's Point, below Mr. Foster's house, and from below the Corinthian Yacht Club House. Although the rock has been described by Sears and Rosenbusch, a few words may be devoted to it. The freshest specimens are

[1] ROSENBUSCH, Tsch. Min. Pet. Mitth., Vol. XI, p. 447, 1890; Mikr. Phys., Vol. II, p. 467, 1896.

[2] SEARS, Bull. Mus., Comp. Zoöl., Vol. XVI. p. 167, 1890.

[3] WADSWORTH, Proc. Boston Soc. Nat. Hist., Vol. XXI, p. 288, 1881.

[4] SEARS, op. cit.

creamy white, weathering to brown, very fine-grained and with a dull luster, and a tendency to schistosity, which largely accounts for the earlier view that this was a sandstone. A few glistening white phenocrysts of anorthoclase are visible.

In thin section the phenocrysts show the characters described by Rosenbusch and Sears. The groundmass is trachytic with pronounced flow-structure, and is composed largely of small alkali-feldspar laths, these being generally clear. The interstitial matter is clear and colorless with low refractive index, partly isotropic and partly feebly doubly refracting. Some of it seems to be glass and some kaolinized feldspar. There is considerable "dust" and many small black and brown specks, the remains of former ferro-magnesian minerals, which, however, never were present in a large amount. Very few traces of these remain, only rare, small biotite flakes being seen. A little quartz is present, but is rare.

Two analyses of this keratophyr are given, one by myself and the other by Dr. Chatard, of the United States Geological Survey, for Mr. Sears. They resemble each other very well, though mine shows a little more silica. It will be noticed that they are not markedly different from the rhyolite, though in this lime is higher.

	I	II
SiO_2	71.40	70.23
TiO_2	....	0.03
Al_2O_3	14.76	15.00
Fe_2O_3	1.68	1.99
FeO	0.72	....
MnO	trace	0.24
MgO	0.55	0.38
CaO	0.10	0.33
Na_2O	4.79	4.98
K_2O	5.16	4.99
H_2O (110°)	....	0.91
H_2O (ignit.)	1.46	1.28
P_2O_5	....	0.06
	100.62	100.42

I. Keratophyr. Boden's Point, Marblehead Neck. H. S. Washington anal.

II. Keratophyr. Boden's Point, Marblehead Neck. T. Chatard anal. Sears, Bull. Mus. Comp. Zoöl., XVI, p. 170, 1890; also Bull. 148, U. S. Geol. Surv., p. 78, 1897.

HENRY S. WASHINGTON.

EDITORIAL

THE great success which has attended the application of photography to the determination of the positions and movements of stars may well stimulate geologists to attempt a similar application to earth movements. It is a not uncommon belief among mountaineers that peaks which were formerly not visible from certain points of view have recently come into sight, and conversely that points formerly in view have disappeared from sight. There is nothing incredible in this if warping is in active progress, and it would seem worthy of being put to the test of exact observation. It would not be difficult to take photographic panoramas from selected points of view, and to record with precision the positions of the camera, so that views could be taken from exactly the same points at subsequent dates. A comparison of such views would serve to show whether any appreciable warping of the crust is in progress or not. The effect of degradation on the one hand, and of snow accumulation, on the other, could easily be eliminated, and the influence of refraction might be avoided by taking the photographs in precisely similar conditions of atmosphere and light, or the proper correction could be made. As this method is probably applicable only to serrate alpine tracts, it is to be hoped that some of the geologists of those regions will interest themselves so far as to take and duly register a first series of photographs so that comparison may be made at some future time.

T. C. C.

THE doctrine of alternate quiesence and readjustment of the crust of the earth serves such a radical function in the interpretation of ancient peneplains, sea-shelves, and epicontinental seas, and in the elucidation of expansional, repressional, and provincial epochs of life evolution, that a precise conception of what

is understood by quiescence and readjustment may aid in the removal of doubts and objections, since some of these seem to be based on a rather too rigid and literal interpretation of the terms quiescence and readjustment and their synonyms. Like most terms which relate to the mutual relations of the sea and the land, or of the continental platforms and the abysmal basins, the term quiescent has a merely relative meaning. It does not necessarily signify an absence of absolute movement toward the center of the earth, but simply an absence of *differential* movement relative to other portions of the crust. If the whole crust sinks toward the earth's center at an equal rate in all its parts, the relations of the continental platforms and the abysmal basins remain essentially undisturbed and may be said to be quiescent. Such a shrinkage may theoretically reduce the capacities of the ocean basins just as it reduces the whole surface of the sphere, and this reduction of basin capacity may cause the sea to overlap the margin of the land in some degree. But this incursion of the sea, would, if appreciable, be justly regarded as only an incident of the quiescent stage. It would indeed be only one of several factors involved in that transgression of the sea which is so characteristic of quiescent stages. It is only when such a common sinking of the crust toward the center develops *differential* stresses of such magnitude as to require a notable warping, crumpling, or faulting of the crust that the relations of the continental platforms to the abysmal basins are seriously disturbed and the quiescent stage is replaced by one of readjustment. It is perhaps even necessary to regard such a common centripetal movement during the quiescent period as a necessary antecedent of the period of readjustment, for such a movement is perhaps necessary to develop the differential stresses out of which the readjustment springs. All objections therefore to the doctrine of periodic quiescence which are based upon the conception of the absence of centripetal motion should be set aside as based upon misconception. The only valid theoretical objections are those which apply to the conception of periods of *concordant* centripetal movement alternating with periods of *discordant* cen-

tripetal movement. The former are quiescent periods so far as the relations of platforms and basins are concerned, the latter are periods of readjustment. The dynamical conception involved in this view is somewhat radically different from that involved in the literal conception of quiescent periods as periods of no crustal movement at all.

In the accumulation of the general stresses which issue in general readjustments, local stresses of special intensity must almost necessarily be developed and these may reach such a degree of intensity as to lead to local readjustments. These local readjustments may result in the distribution of the stresses over wider areas, and these wider areas may in time yield and transmit the stresses to still broader fields until the stresses become general and reach such a degree of intensity as to issue in a general readjustment. Local readjustments in the form of local warpings and faultings may be incidents of the general quiescent stages, and like them may be essential antecedents of general readjustments involving the formation of mountain systems and similar pronounced phenomena.

T. C. C.

THE DUPLICATION OF GEOLOGIC FORMATION NAMES

THE custom of giving more or less local geographic names to geologic subdivisions has become so universal that we are even now duplicating the use of such names to a considerable extent. Geological literature is of too great bulk for the working geologist to attempt to ascertain whether or not names which he proposes to use have been preoccupied. To illustrate what the present system is leading to a few instances of some prominence will be cited.

In 1883 Hague described, in a report of the United States Geological Survey the Eureka quartzite, a subdivision of the Silurian in the Eureka district, Nevada. In 1891 Simonds and

Hopkins, in a report of the Arkansas Geological Survey, used the name Eureka shale for a supposed Devonian horizon; while in 1898 Haworth, in a report of the Kansas Geological Survey, proposes the name Eureka limestone as a subdivision of the Coal Measures.

In 1879 Peale, in the Eleventh Annual Report of the United States Geological and Geographical Survey of the Territories, employed the term Cache Valley group for a subdivision of the Pleistocene of Utah. Becker described in 1888 the Cache Lake beds of California, in Monograph XIII of the United States Geological Survey, and referred them to the Tertiary. In 1896 G. M. Dawson, in a report of the Canada Geological Survey, uses the name Cache Creek formation for a horizon of the Carboniferous to include strata described by Selwyn in 1872 as Upper and Lower Cache Creek beds.

In 1842–1846 Emmons, Vanuxem and Mather employed the term Erie division as a subdivision of the New York system. In the Ohio Geological Survey reports the Erie clay was used as a subdivision of the Pleistocene, and Erie shale was referred both to the Carboniferous and Devonian. In 1875 Lesley described, in a report of the Pennsylvania Geological Survey, the Erie shale, which he referred to the Silurian. In 1898 Haworth described the Erie limestone of the Coal Measures of Kansas. The above references are given merely to illustrate the confusion that is likely to arise from the use of new geographic terms if the literature is not carefully examined for previous use.

For the past eighteen months the writer has been engaged in preparing a card catalogue of geologic formation names, during such time as could be taken from other office and field work. This catalogue has already assumed considerable proportions, and is now being consulted by those geologists who are aware that such a work is being prosecuted. While preparing the annual bibliography of geological literature for 1898 the writer has found several instances of duplication of names that have become well established in geological nomenclature. It will

probably be a year or more before this catalogue can be published, and, in the meantime, to assist in avoiding such duplication, the writer offers to furnish geologists, who will correspond with him, such information as he possesses, regarding names which they propose to use as formation names.

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Reviews

Experimental Investigation of the Formation of Minerals in an Igneous Magma.[1] A review.

Professor Morozewicz has at length published in German the results of five years' elaborate experimentation on the synthesis of minerals and of volcanic rocks. This work is the most exhaustive of its kind since Fouqué and Lévy's epoch-making experiments, published in Paris in 1882. The wide scope and large scale of the experiments of Morozewicz, and the very complete chemical investigation of his products, together with carefully devised reference to the geological application, make this new work worthy of extended review and of careful study by geologists.

The motive of the experimenter was primarily to imitate, as nearly as possible, natural igneous magmas, and by fusion of carefully prepared chemical mixtures in a large glass furnace to produce crystalline masses in sufficient volume for isolation and chemical investigation of the component artificial minerals. The author lays stress upon the importance of more careful work in the chemistry of the silicates in mineralogy, and the chemistry of silicate mixtures or solutions in petrography. For the former the work of Lemberg and Thugutt is quoted as of primary importance, and for the latter Lagorio and Vogt have initiated methods of research that should be emulated for more complete understanding of the nature of igneous rocks. The work of Fouqué and M. Lévy was limited to microscopic investigation of the products of fusion in small platinum crucibles in the Fourquignon furnace. Morozewicz obtained the use of a corner in a large Siemens furnace, in a glass factory near Warsaw; the interior of this furnace is much of the time at white heat and continuously so for periods of weeks and months. The furnace is heated by a blast of carbonic monoxide mixed with air, and the temperature to which the crucibles were sub-

[1] JOSEF MOROZEWICZ (Warsaw). Experimentelle Untresuchungen über die Bildung der Minerale im Magma. Tschermak's Mineralog. u. Petrogr. Mittheilungen, Bd. XVIII, H. 1–2–3, pp. 1–90 and 105–240, 8 Plates, 1898.

jected was estimated to vary from 1600° down to 500° C. Two openings, half a foot long each, were arranged in the side of the furnace so that crucibles could easily be inserted and removed. The temperature within the entrance chamber was much less than in the heart of the furnace, and by placing a crucible first in the innermost glow, then at the inner mouth of the chamber, and lastly, a short distance within the chamber, conditions of gradual cooling and crystallization could be brought about. From day to day at certain periods there were variations in the temperature of the furnace itself due to the requirements of glass manufacture which went on as usual in the huge crucibles of the factory, and these changes affected to a certain extent the crystal structures obtained. Fire-clay crucibles of various sizes were used, the melting being done in large crucibles, the crystallization in smaller ones of 150 c. c. capacity. The crucibles when filled were carefully covered and placed on refractory tiles. They were first warmed to dark red heat and then thrust into the position of maximum temperature. After a few hours they were drawn to the second position at the inner mouth of the opening, and finally, after remaining there for several days were drawn within the small chamber where they finally cooled.

Crystallization lasted commonly from one to three weeks, but in exceptional cases the crucibles were left in the furnace as long as two and one half months. A few experiments were made on a very large scale in the great factory crucibles where over a hundred pounds of mineral matter was molten at a time. It was found that certain mixtures corroded the crucible violently, while others remained unaffected by contact with the crucible walls. Magmas with high magnesia and low alumina and alkalies acted violently upon the clay, because magnesia has, at these high temperatures, a very strong affinity for alumina, and in the absence of alumina from the mixture combines readily with that which forms the containing vessel. Mixtures of lime and the alkalies, rich in alumina, do not affect the crucible, even after long exposure to the highest temperatures. About two hundred experiments were made in all, and of these 25 per cent. failed owing to various causes. The others produced coarsely crystalline mineral masses in many cases, so that isolation of the minerals for analysis could be accomplished. The mixtures used were prepared usually from pure chemicals Silica was used in the form of the hydrate $SiO_2.3H_2O$; alumina as hydrargillite ($Al_2O_3.3H_2O$); lime, magnesia, and the alkalies as carbon-

ates, iron oxide as hematite, and instead of ferrous iron was used either siderite ($FeCO_3$) or a fayalite-slag (Fe_2SiO_4).

The pulverized substances were intimately mingled and at first carefully heated to drive off the water. For the larger and coarser experiments common commercial mixtures were used, but in all cases the proportions were calculated as nearly as possible with reference to the known composition of igneous rocks. For a special group of experiments, combinations of minerals in theoretical proportion were prepared, in order to test the theory of solutions; the rock-forming silicates are conceived as capable of supersaturation of a magma, and, in proportion to their relative amounts and the nature of the solvent, crystallize out in the order of saturation; all the mineral products were carefully analyzed and the results were checked in each case by carefully sampled quantitative analysis of the mixture *after fusion*, in order that the effect of the addition of new silica or alumina from the crucible walls, by corrosion, might be allowed for. Finally, a special group of experiments involved the melting up of pieces of natural rocks, granite, andesite, basalt and others, and these experiments the author is still carrying on.

The following list will show the great variety of minerals produced by so-called "dry fusion" from silicate magmas:

1. Oxides: Corundum, Hematite, Ilmenite, Quartz, Tridymite, and a peculiar prismatic variety of SiO_2.

2. Aluminates and Ferrates: Spinel, Chlorospinel, Pleonast, Hercynite, Magnoferrite, Magnetite.

3. Silicates: Sillimanite, Cordierite, Olivine, Forsterite, Fayalite, Monticellite, Enstatite, Hypersthene, Augite, Alkaline Augite, Pleochroic green Augite, Diopside, Wollastonite, Biotite, Lepidomelane, Sanidine, Labradorite, Anorthite, Melilite, Nepheline, Haüyne, Nosean, Sodalite, and Lagoriolite.

The following volcanic rocks were artificially produced: Rhyolite, with flow structures, spherulitic basalt-obsidian; enstatite-basalt with both intersertal-glassy and micro-porphyritic structures; normal basalt with micro-porphyritic structure; augitite with hyalopilitic groundmass; melilite-basalt in both micro-porphyritic and granular forms; and haüyne rocks of intersertal-glassy and granular structures. From mixtures supersaturated with alumina were produced mineral aggregates bearing abundantly crystalline Al_2O_3 in the form of corundum and related minerals. Among these were a cordierite-andesite of glassy or

micro-porphyritic structure, and ophitic spinel-basalt, a spinel-bearing feldspathic basalt of micro-porphyritic and divergent-radial structure, a corundum-bearing nepheline-basalt, melilite-basalt bearing spinel, corundum-nephelinite, and coarsely trachytic corundum-bearing anorthite-nepheline mixtures.

Corundum and spinel have frequently been obtained synthetically by both "wet" and dry methods, and an examination of the literature, no less than the casual production of these minerals in preliminary experiments, showed that an excess of alumina readily induces the crystallization of free Al_2O_3, in the form of corundum, and with relatively high magnesia and iron in addition, produces spinel. The minerals were isolated and analyzed; both green and black varieties of spinel were obtained, the one chlorospinel, the others pleonast and hercynite. A comparison of the magma analyses with the relative amounts of these minerals produced, shows that alumina plays the principal rôle in the production of spinel as well as corundum. On the hypothesis that the crystallization of free alumina indicates supersaturation, it was believed that precise saturation, or the condition of the magma after the excess of Al_2O_3 had crystallized out, should give a ratio of alumina to the bases of 1 : 1, that being a constant in most of the aluminosilicates (feldspar, nepheline, haüyne, sodalite, mica, etc.). This was confirmed by eight analyses of the glass from which the corundum and spinel had crystallized; these gave the ratios

$(K_2O-Na_2O-CaO):Al_2O_3:SiO_2=$ (1b) 0.9:1:1.9; (2b) 0.9:1:2.3; (3b) 0.9:1:2.3; (4b) 0.9:1:2.3; (5b) 0.9:1:2.3; (6b) 1.2:1:1.9; (7b) 1.1:1:3.4; (8b) 1:1:3.2.

Thus with variable silica, the ratio of Al_2O_3 to the bases averaged $= 1$.

To confirm this result a special series of test mixtures were melted up and crystallized. These tests, made variously with magmas of the composition of basic and acid feldspars, with the alkalies and silica in varying proportions, and under varying conditions of cooling, gave the following important results:

1. A silicate magma is saturated with alumina, when the ratio of the bases to alumina is equal to 1.

2. Saturated aluminosilicate magmas of mixed composition and of varying silica contents, are capable at high temperatures of dissolving alumina and forming supersaturated solutions.

3. Pure soda-aluminosilicate magmas dissolve alumina in large

quantities; lime-magmas in small quantity and pure potash-magmas are, under the same conditions, incapable of dissolving alumina in excess.

4. Supersaturated aluminosilicate magmas, whether of mixed silicates or simple, with the general composition $MeO.mAl_2O_3.nSi\ O_2$ ($Me = K_2, Na_2, Ca$, $n = 2 - 13$), throw out all the excess of alumina (over $m = 1$) in the form of corundum crystals, when magnesia and iron are absent, and n is less than 6; in the form of sillimanite (or sillimanite and corundum) when n is greater than 6; in the form of spinel (or spinel and corundum) when the magma is rich in magnesia and iron and n is less than 6; or in the form of cordierite (or cordierite and spinel) when Mg and Fe are present and n is greater than 6. In the last two cases sillimanite and corundum may also sometimes crystallize out.

5. The amount of spinel or sillimanite, from magmas rich in magnesia or silica, depends wholly on the excess of alumina present. The same is also true of corundum.

6. The crystallization of corundum and spinel depends, not on the "basicity" of the magma, but only on the ratio of the bases (K_2O, Na_2O, CaO) to alumina. In the experiments, corundum crystallized out from magmas varying in silica from 0 (sodic-aluminate) to 13 (Rhyolite).

7. Rules 4 and 5 are not wholly true for those magmas which contain basic non-aluminous silicates like augite and olivine in any considerable quantity.

8. Corundum, spinel, sillimanite, and cordierite crystallize from silicate magmas according to the general laws governing crystallization from solutions.

In nature, magmas with alumina in excess occur, but are not very common. There are numerous cases of the primary occurrence of corundum, spinel, sillimanite, and cordierite in both plutonic and volcanic eruptives. The development of these minerals about inclusions and by contact metamorphism in clay slates is well known. These four minerals form a genetic group of close affinity in mode of origin. In the Urals there are numerous orthoclase-corundum rocks classed as pegmatites and syenites. Morozewicz describes fully a new type of great interest to petrographers, and of especial interest in connection with his experiments; the new rock he names Kyschtymite after the Kyschtym district in the Urals: it consists of a medium-grained mix-

ture of idiomorphic corundum of pyramidal habit, with anorthite and biotite, and accessory dark green spinel of earlier generation than the corundum, with also apatite and zircon.

A number of remarkable experiments were made with acid magmas of the general composition of rhyolite or granite. By dry fusion at high temperatures it has frequently been demonstrated that tridymite is a more stable form of crystalline silica than quartz. In the case of the partial fusion of a quartzose block of granite, the quartz became transmuted into an aggregate of shingly tridymite flakes, and the same has been noted in nature in inclusions of granite in a porphyry. The presence of alumina in an acid magma was found to prevent crystallization, where a non-aluminous silicate mixture partially crystallized in the form of tridymite and prismatic silica (the latter of the unusual type described by Fouqué and M. Lévy). Vogt, in his exhaustive studies of furnace slags,[1] has called attention to the influence of alumina in "retarding" the crystallization of a glass or a slag, and this fact is well known to glass workers who add alumina to prevent the development of silicate crystals. With the aid of the theory of solutions, this influence is easily explained; in general, supersaturated solutions give large crystals, a lower degree of saturation gives small crystals, and unsaturated solutions under the same conditions develop no crystals at all. Alkaline silicate magmas are capable of dissolving alumina in large quantities; alumina possesses for the alkalies and more especially the alkaline earths a very strong chemical affinity, forming with them very stable and widespread natural compounds. Accordingly alumina in small amount dissolved in such a magma has only the effect of uniting with a portion of the bases in potential aluminosilicate form, and preventing them from crystallizing out as simple silicates which in the absence of alumina would easily saturate the solution. Morozewicz has demonstrated that a very large amount of alumina is required to saturate a solution to the effect of permitting crystallization of the aluminosilicates, as outlined above. When great excess of alumina is present, however, crystallization may be readily induced. Thus the expression, "retarding crystallization," is applicable only to access of alumina up to the critical point of saturation, beyond this its effect is that of an accelerator. The effect, in fine, of a small amount of alumina in a glass, is to produce aluminosilicate

[1] Vogt, J. H. L.: Beiträge zur Kenntnis der Gesetze der Mineralbildung in Schmelzmassen und in den neovulcanischen Ergussgesteinen, Christiania, 1892.

molecular combinations, without saturation, and solidification takes the form of Van t'Hoff's "solid solution," namely an amorphous glass.

Rhyolite and trachyte magmas, with the Al_2O_3 percentage varyng from 6 to 20, were fused in large masses under varying conditions, of cooling and for periods of a fortnight or more, solidifying invariably as structureless glass; the same magmas, it will be remembered, with an excess of alumina, developed the minerals of the corundum group with the greatest ease. The attempts were repeated with fluorides and phosphates added, but again without result. Finally success was obtained by adding 1 per cent. of tungstic acid to a rhyolite mixture of the following composition:

SiO_2	77.9
Al_2O_3	12.0
FeO	1.3
CaO	0.8
MgO	0.13
K_2O	3.3
Na_2O	4.6

A completely homogeneous glass was formed by the first fusion in the hottest part of the furnace, and partial crystallization was obtained by leaving the crucible at the inner mouth of the entrance chamber for fourteen days—a temperature estimated to vary between 800° and 1000° C. A heterogeneous mass showing flow structures resulted, yellow and white streaks alternating with bands of gray glass. In the microscope the white zones proved to be aggregates of myriads of bipyramidal quartz microlites, of hexagonal form, extinguishing parallel to the vertical axis, and optically positive. The yellowish streaks were much more abundant than the white, and proved to be composed of hexagonal plates of biotite of very perfect form and showing the truncated edges of the combination: (001) (111) $(1\bar{1}1)$ (011). The absorption scheme, pleochroism, color, extinction and double refraction all agree with the properties of biotite. Many of the crystals show corrosion phenomena. Finally abundant aggregates of transparent prisms were observed, sometimes in spherulitic grouping, with extinction usually parallel and occasional twinning. These were believed to be sanidine. There were some other indeterminate colored grains and spicular crystals. The groundmass was essentially an isotropic glass, but showed a spicular microfelsitic structure. There had thus been reproduced by "dry fusion," with the aid of tungstic acid, an association

of the essential minerals of granite—quartz, mica and acid feldspar. The influence of the tungstic acid the author believes to be as follows: after the temperature in the first melting has passed 1000°, neither tridymite nor quartz can form, because at these high temperatures the silica unites with alkalies to form a silicate, in which the tungstic acid is absorbed; it is believed that on lowering the temperature (the position of crucible which ultimately produced crystallization) the absorbed tungstic acid has the effect of decomposing these alkaline silicates and liberating the silica to form quartz. It is not known what compounds the tungstic acid finally forms. Dr. Morozewicz objects strongly to the use of the term "mineralizer," and considers that much harm has been done to the progress of synthetic mineralogy by attributing all obscure reactions to the "mystical action of a mineralizer." He insists that "agent minéralisateur" has no scientific meaning and should be banished from the vocabulary of the mineralogist. This would seem a little unreasonable, in view of the fact that he himself acknowledges that his only success in obtaining crystallization of the granitic minerals was due to the action of a small amount of tungstic acid, which he explains by what at best is only an incomplete hypothesis. Modern petrographers have not ascribed any "mystical" power to the compounds of tungsten, zirconium, boron, fluorine, etc., but have observed that these elements are minor but invariable accompaniments of the crystallization of coarse acid pegmatites. Morozewicz has only added confirmatory evidence from synthesis of the actual importance of these agents to promote crystallization in an acid magma, and whatever they be called, their influence, whether chemical or physical, cannot be denied. Possibly the word "crystallizer" would be more exact than "mineralizer." It is certainly true, on the other hand, as Morozewicz points out, that this latter word has been much abused, and simple reactions have been allowed to pass unexplained as due to the action of a mineralizer, because a fluoride or a borate chanced to be in the equation.

The accompanying plates are reproduced to show the coarseness of crystallization obtained with basic magmas. The basic magmas are those still capable of dissolving free alumina, or, in other words, unsaturated. An enstatite basalt was produced from a mixture of three parts olivine, three parts labradorite, and one part augite. A large mass of this material was fused, a smaller quantity being separated for fusion with iron oxide (hematite) alone, the principal mass having a little

charcoal added to reduce the hematite present to the ferrous condition.

The smaller portion, after crystallization for twenty days, gave a well crystallized yellowish-brown mass. Pyroxene crystals could be seen with the naked eye. In the vesicles of the slag were remnants of unmelted hematite, as well as newly crystallized hematite flakes and brilliant spicular pyroxene crystals, sometimes 1^{mm} long. These crystals showed distinct prismatic, pinacoidal and pyramidal faces, pleochroism, and parallel extinction. In thin section, as shown in Plate IV, Fig. 2, distinct porphyritic structure was observed, with idiomorphic enstatite and olivine in a groundmass consisting of monoclinic pyroxene, plagioclase, magnetite, and a small quantity of glass. The olivine was in short crystals, completely transparent and colorless, of very strong double refraction and parallel extinction. The greater part of the olivine crystallized in spherical concretions. The plagioclase of the groundmass showed twinning with extinctions varying from 10° to 27°, hence, a labradorite. Its crystallization was earlier than the other components of the groundmass. The augite formed aggregates of prisms partly as small phenocrysts, but principally in the groundmass. The order of crystallization was thus olivine, enstatite, monoclinic pyroxene, labradorite, magnetite and augite, glass. The larger mass (over 100 pounds), gave also an enstatite basalt (Plate IV, Fig. 1) with crystals of both orthorhombic and monoclinic pyroxene, and olivine, in a colorless groundmass. This groundmass appeared to be a completely homogeneous colorless glass. Pieces of this glass, heated three days at the temperature of red glow without melting, acquired a trachytic crystalline habit of rough surface, and lost their original glassy luster. The groundmass by this heating, developed a crystalline mixture of tiny plagioclase and augite microlites, showing that long continued application of heat to a supersaturated solution, even in solid condition, could bring about crystallization. In order to test the temperature necessary to produce crystallization, the following experiments were devised. Six crucibles were filled with fragments of this slag and placed in a row between the hottest part of the interior of the furnace and the middle of the entrance chamber. At the end of a month it appeared that the innermost four crucibles contained only glass, which had strongly corroded the crucible walls; while in the fifth and sixth crucibles (those within the chamber) crystalline products had formed. An investigation of preparations from these crucibles showed that the order of crystallization of the component minerals was the same

throughout and forms a constant function of the chemical composition of the magma. Period of crystallization and temperature have an important influence only on the structure of the resulting rock.

The second plate here reproduced (Pl. VII) shows the products of crystallization from an anorthite-nepheline magma without magnesia, consisting principally of corundum, anorthite, and nepheline. This was fused in large masses, producing a well crystallized gray rock. In the microscope the principal mineral is seen to be plagioclase prisms in long rectangular form with distinct cleavage and multiple twinning. Between the plagioclase laths is a groundmass consisting of nepheline, magnetite and glass. The physical properties of this plagioclase are essentially those of anorthite (An_6 Ab_1) with the following chemical composition:

SiO_2	46.5
Al_2O_3	34.6
CaO	17.3
Na_2O	1.6

Corundum is enclosed in the plagioclase in the form of circular plates. The groundmass contains many small microlites of magnetite, forming sometimes a rectangular network. Nepheline occurs in short, hexagonal prisms and irregular masses, forming the greater part of the groundmass. There are, in addition, pleochroic yellowish corroded crystalline flakes, which are probably lepidomelane. The glass base occurs in variable quantity in different parts of the crucible.

The systematic subdivision of aluminosilicate magmas, in relation to these experiments, deserves especially thorough examination. The greater part of known eruptives on the surface of the earth belongs to the aluminosilicate group of magmas. The principal and most stable components of magmas are silica and alumina, while the bases are variable and easily replace each other to form both minerals and rocks. Both SiO_2 and Al_2O_3 are capable of crystallizing out in free form by supersaturation, and both (according to the experiments of Thugutt[1] and the theoretical conception of Wernadskij[2]) are capable of playing chemically the part of acids. Silica and alumina are thus conceived to have an analogous systematic significance in the classification of eruptive magmas, granite being a magma supersaturated with silica, and

[1] ST. THUGUTT, Zur Chemie einiger Alumosilicate. N. J. f. M., 1895, B.-Bd. IX,

[2] W. WERNADSKIJ, Ueber die Sillimanitgruppe, sowie die Rolle der Thonerde in Silicaten. Moscow, 1891 (Russian).

corundum-syenite a magma supersaturated with alumina. Alumino-silicate magmas are thus divided into two great analogous groups, each of which is subdivided into three types, as follows:

GROUP A

1. Magmas supersaturated with Al_2O_3.
2. Magmas saturated with Al_2O_3.
3. Magmas not saturated with Al_2O_3.

GROUP B

1. Magmas supersaturated with SiO_2.
2. Magmas saturated with SiO_2.
3. Magmas not saturated with SiO_2.

In both groups type 2 is the same, a syenite or trachyte magma, simultaneously saturated with both alumina and silica. There are thus five principal types in all, as follows:

1. Magma supersaturated with alumina: corundum-syenite, bearing alkaline feldspars, and kyschtymite bearing lime-soda feldspars.

2. Magma supersaturated with silica: granites, rhyolites, quartz-diorites, dacites, etc.

3. Magma saturated simultaneously with alumina and silica: mica-syenite, trachyte, mica-diorite, and mica-andesite. In this magma the aluminosilicates are the essential minerals. The pure metasilicates and orthosilicates are accessory or absent.

4. Magma not saturated with alumina: gabbro, basalt, diabase pyroxenite and other basic rocks. Obviously this magma is also not saturated with SiO_2.

5. Magma not fully saturated with SiO_2: elaeolite-syenite, phonolite, leucitite, etc.

The magma types 4 and 5 are not identical. A biotite-elaeolite-syenite can be saturated with Al_2O_3 and not fully saturated with SiO_2. In the same way some nepheline rocks may be considered as saturated with Al_2O_3, but do not contain sufficient silica to develop free quartz. In the above scheme it is of course obvious that the rocks belonging to the first type of Group A are least widespread according to our present knowledge of the geology of the earth, and will be discovered, in the opinion of the author, in greater quantity in the future.

It will be seen that in these experiments all the essential minerals of the "neovolcanic lavas" have been reproduced with the exception

of hornblende, and also many rock structures of characteristic habit. These structures are proved to be the result of external conditions of crystallization and also of chemical composition, both in qualitative and quantitative sense. The order of crystallization of the individual minerals depends on no one factor, such as "fusibility" or "acidity," but is the result of a complex equation in which, perhaps, the most important element is the ratio of the quantities of the several compounds dissolved in and composing the solution. One and the same compound can begin to crystallize out sooner or later than another according to the amount which is present. The order of crystallization is different in different magmas, and different substances have different capacity for forming saturated solutions in an aluminosilicate magma. In certain cases temperature has an important influence: magnetite, for instance, forms a saturated solution best at temperatures below 1000° C. At higher temperatures it crystallizes out after olivine. Anorthite crystallizes out more easily at a higher temperature (over 1000°). The process is obviously much complicated by the changes in the magma itself as a solvent, by progressive crystallization of the compounds composing it.

The following are a few of the principles defined by observations up to this date; but final laws of silicate saturation can only be attained by many experiments of character similar to these, which, as in the advanced synthetic work of organic chemistry, shall have thrown light on the structural formulae and atomic relationships of the silicates.

1. Corundum, spinel, sillimanite, and cordierite in magmas supersaturated with alumina, are the first products of crystallization. Spinel and sillimanite crystallize before corundum.

2. Magnetite at a temperature below 1000° crystallizes out in proportion to the supersaturation of a solution with ferric iron and to the amount of other iron compounds. It crystallizes sometimes before and sometimes after augite and plagioclase according to their relative amounts.

3. The different orthosilicates of the type Me_2SiO_4 (olivine, etc.) crystallize first from a magma not supersaturated with alumina.

4. Rhombic pyroxene develops earlier than augite, if the molecular ratio of magnesia (and ferrous iron) to lime is about three or more.

5. The crystallization of augite is very variable.

6. In a magma with haüyne (33 per cent.) in excess of anorthite (23 per cent.) the haüyne crystallizes first.

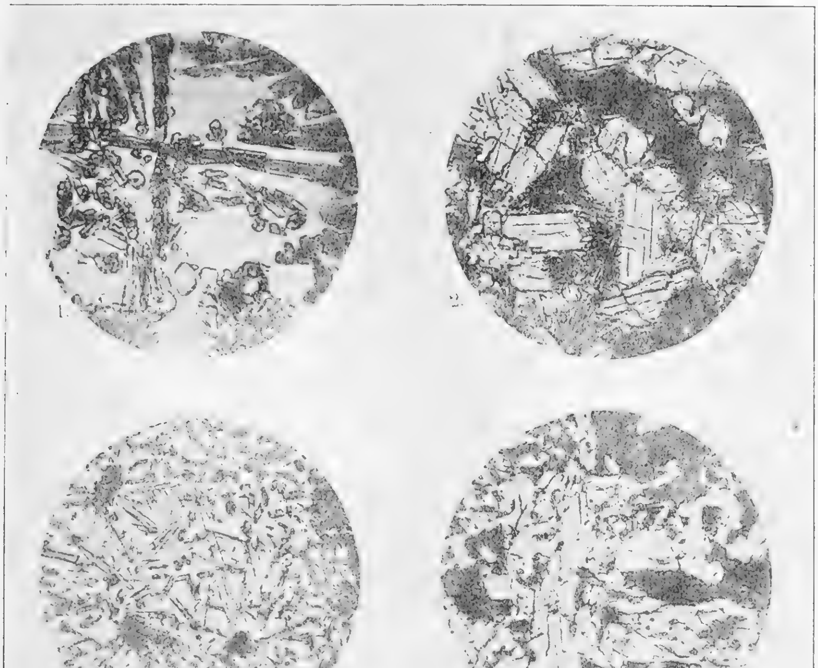
7. In a magma with the ratio of bases to alumina greater than 1, melilite crystallizes after olivine and simultaneously with anorthite.

8. Plagioclase begins to crystallize after olivine, and in many cases after augite, according to the amount present. Nepheline is one of the latest products of crystallization, forming usually a groundmass product between plagioclase laths (mesostasis).

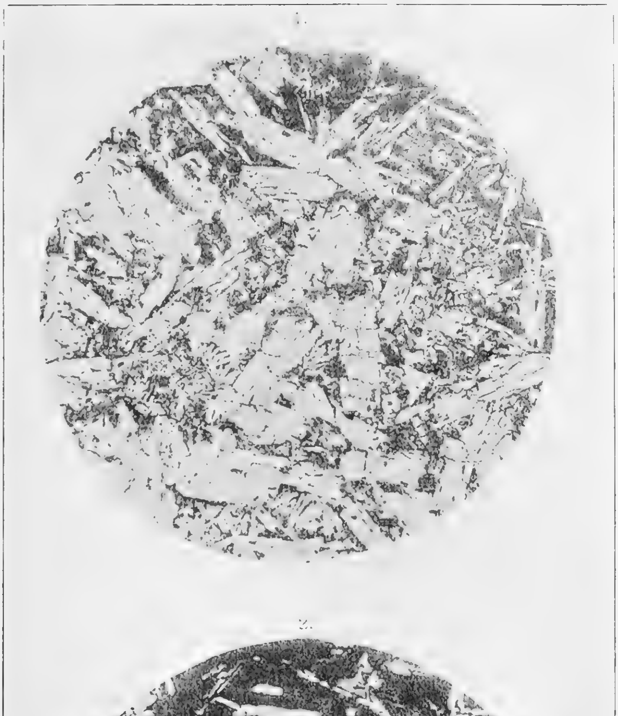
10. The glassy groundmass represents an uncrystallized solid solution and frequently has the composition ($MeO.2SiO_2$) of Lagorio's "normal glass."

With respect to the question of magmatic differentiation, Morozewicz favors rather the hypothesis of one primary magma, chemically differentiated for a single region by means of processes determined in the main by the laws which govern solutions. In many of the experiments described a single crucible showed remarkable variations in structure, coloring, and composition locally. This was especially true of magmas rich in the alkaline earths. In a 100–pound mass, consisting chiefly of alkaline augite, the lower portion showed throughout a higher specific gravity than the upper, with much magnetite below and none above. In common glass-melting, separation of layers of higher specific gravity in the bottom of the crucible has been noticed, these being especially rich in iron, lime, and magnesia. A mass of granite weighing two pounds was melted in large pieces in the hottest part of the furnace, and allowed to glow at the inner entrance of the chamber for five days, producing a glassy mass below with quartz grains unmelted and partially altered to tridymite above. These quartz grains had apparently been floating in the glass; the glassy portion appeared fully homogeneous and was of uniform color; in fact, however, careful separate analyses of the upper and lower portions of the glass showed not only that the upper portion was richer in silica, but that the ratio of the bases was different. Thus Fe_2O_3 showed in the lower layers an increase of .8, MgO of .7, CaO of .4, and alumina of .2. The specific gravity of the lower part was about .1 greater than the upper. The silica percentage of the upper part was 73.65, of the lower part only 59.20. Thus the iron and alkaline earths settled to the bottom, and the silica and alkalies remain in excess above. It is significant that these substances (FeO, MgO and CaO) which form the lower stratum of glass, are the ones which crystallize out earliest from silicate magmas.

In conclusion the reviewer would call the attention of geologists



SYNTHETIC EXPERIMENTS BY MOROZEWICZ



SYNTHETHIC EXPERIMENTS BY MOROZEWICZ

and petrographers to the accompanying plates reproduced from this remarkable monograph, and to the importance of careful study of the results of such experimentation in connection with research in the field. Dr. Morozewicz has written the results of his elaborate synthetic studies in most compact and readable form, the work being contained in 225 pages systematically arranged, well indexed, with each chapter carefully summarized as well as the whole work. He has shown that the synthetic production of rock-making minerals is possible under conditions attainable in any of our large cities, and his work should be a stimulus to further endeavor of the same sort. Analytical work alone is no more capable of solving many difficult problems connected with the origin of the igneous rocks and of ore deposits than are the methods of microscopical petrography. Morozewicz has shown that the same synthetic treatment is applicable to the chemistry of the silicates that has been used for years in the case of the hydro-carbon compounds.

T. A. JAGGAR, JR.

CAMBRIDGE, MASS.

PLATE III.

Fig. 1. Enstatite-basalt, first stage: olivine, enstatite, monoclinic pyroxene, glassy groundmass; enlarged × 60.

Fig. 2. Enstatite-basalt, second stage; micro-porphyritic structure: large enstatite crystals in a groundmass which consists of augite, labradorite, olivine, and magnetite; enlarged × 60.

Fig. 3. Normal basalt, first stage; augite and magnetite microlites in glassy groundmass (hyalopilitic); enlarged × 60.

Fig. 4. Normal basalt, second stage: great augite masses with inclusions of olivine and magnetite; brown groundmass; enlarged × 60.

Fig. 5. Enstatite-basalt: olivine concretions seen below; enlarged × 60.

Fig. 6. Basalt without olivine, ophitic structure: long plagioclase prisms with augite in the interspaces; black grains of spinel and magnetite; enlarged × 60.

PLATE IV.

Fig. 1. Anorthite-nepheline magma: large anorthite crystals with cleavage cracks and multiple twinning; in the groundmass occurs nepheline, arborescent magnetite forms, etc.; ordinary light, enlarged × 15.

Fig. 2. The same between crossed nicols in polarized light.

Physical Geography of New Jersey. By ROLLIN D. SALISBURY; with an appendix by CORNELIUS CLARKSON VERMEULE. Being Vol. IV of the Final Report of the State Geologist. 8vo, pp. xvi + 170 + 200. Trenton, 1898.

New Jersey has set a good example for her sister states in the character and quality of the physiographic work set forth in this volume. Other states have made an enviable record in other lines of geologic work, but this is the first complete treatment of the physiography of a state we have had in America; and it is all the more notable for having as its author a specialist in physiography of the highest ability.

The plan of the work is, first, a plain statement of the facts of topography in detail, in the three natural topographic regions of the state, and second, the history of the topography.

The State of New Jersey, as a whole, is a part of the Atlantic slope, and though it is only 166 miles long, by about 40 miles wide, it includes portions of all the natural sub-provinces of this slope, *i. e.*, the coastal plain, the Piedmont plateau, and the Appalachian zone. Professor Salisbury shows that to this series another term should be added for the area under consideration, the series then reading from northwest to southeast; (1) *Appalachian* zone, of folded strata; (2) the *highland* area, of crystalline schists; (3) the *piedmont plain*, of Triassic rocks; (4) the *coastal plain*, of Cretaceous and younger strata, this last division covering a little more than the southern half of the state.

The members of this series all have their boundaries practically parallel with the Atlantic Coast, and as they differ widely in the nature of the materials from which they are built, the structure furnishes the natural basis for the division into zones, the topography being of the greatest importance in the interpretation of the geology. These four successive zones have a general slope to the southeast, directly across the structural boundaries, the inner or Appalachian zone having an average altitude of over 1500 feet, while the outer or coastal plain nowhere rises above 400 feet, by far the larger part of it being below 100 feet.

The Appalachian zone consists of early clastics, much folded, the axis of folding being northeast and southwest. Erosion has hollowed out broad valleys in the softer materials, and has left the harder beds standing up as long ridge-like mountains.

The second or Highlands area, made up of crystalline schists, does

not show the topographic regularity which the structure has imposed upon the inner zone, yet it has a deal of relief, being made of block-like mountain masses, flat-topped, of nearly equal elevation, nowhere rising into peaks, and separated by rather broad valleys, so giving an arrangement of two or three ranges of hills with the general northeast-southwest trend.

The third area, the Piedmont plain, has an undulating surface, sloping to southeast, yet interrupted by conspicuous ridges, one of which fronts the Hudson as the Palisades. These ridges are outcrops of trap, and represent dikes or flows of igneous rock.

The coastal plain is coincident with the Cretaceous and later deposits. In the description of all these zones, plates are given, showing various cross-sections drawn to scale, very helpful in getting a clear conception of the actual topographic conditions.

With such a complex structure, erosion has ever been busy, and by the differential erosion, and deposition, a basis is given by which the ever-varying attitude of the land is put on record. This very complex history Professor Salisbury and his assistants have deciphered for the long lapse of geologic time since the Triassic, so a tolerably connected history is given us from the beginning of Cretaceous time, and the ups and downs on record in this area give a very vivid conception of the instability of the earth's crust or the ocean level, or both.

There was a post-Triassic uplift when the Schooley peneplain was formed; then a Cretaceous subsidence and considerable deposits formed; then a slight post-Cretaceous uplift; then a Miocene submergence and more deposition; another elevation and the formation of the great Kittatinny and other valleys, and the emergence of the Palisades by differential erosion; another submergence — the Pensauken — when a broad sound extended from New York Bay southwest to the Chesapeake, and the coastal plain was only half above the sea, as a fringe of sandy islands; then a slight uplift and further erosion, during which time the glacial epoch brought its mantle of ice to the middle of the state, slightly masking the detail of the topography by erosion and deposition of drift; during which time also the southern half of the state was submerged; lastly, a postglacial elevation to present altitude.

This long record is made out by the most careful study of the physiography, by the intelligent mapping and correlation of a vast

mass of detail, and the whole interpretation stands as a monumental work in the young science of physiography.

The complexity of structure, the varying altitudes, the differential erosion, and the glacial interference have given many beautiful examples of readjusted drainage, some cases of which, *e. g.*, the Raritan and the Passaic, deserve to become classic.

The chief changes in postglacial time have been in the way of some readjustments of drainage in the drift, the beach action along the coast, and the building of dunes.

The whole of Part II, pp. 65–170 will be found a very valuable help to the teacher of physiography, and, for these pages alone, should be in every teacher's library. No plainer general statement of river action can be found than is here given (pp. 70–79).

The book is generously provided with maps of fine quality, with diagrams and sections, and with exceptionally clear half-tone insets of characteristic landscapes, all of which add very materially to the value of the work.

In the Appendix is collected a large mass of data, tables of geographical positions, of beachmarks, areas of drainage basins, forest areas, and tide tables. An account of the nationality and distribution of the population, and a statement of work accomplished in the magnetic survey closes the volume.

J. P. Goode.

Bulletin of the American Museum of Natural History. Vol. X. 1898. New York.

Article IV. *A Complete Skeleton of Teleoceras fossiger. Notes upon the Growth and Sexual Characters of this Species.* By Henry Fairfield Osborn.

Article VI. *A Complete Skeleton of Coryphodon radians. Notes upon the Locomotion of this Animal.* By Henry Fairfield Osborn.

Article VII. *The Extinct Camelidae of North America and Some Associated Forms.* By J. L. Wortman, M.D.

Article IX. *Remounted Skeleton of Phenacodus primaevus. Comparison with Euprotogonia.* By Henry Fairfield Osborn.

Article XI. *Evolution of the Amblypoda,* Part I. *Taligrada and Pantodonta.* By HENRY FAIRFIELD OSBORN.

Article XII. *Additional Characters of the Great Herbivorous Dinosaur Camarasaurus.* By HENRY FAIRFIELD OSBORN.

Students of vertebrate paleontology will find interesting material in this bulletin. Professor H. F. Osborn contributes five articles and Dr. J. L. Wortman contributes one. Professor Osborn describes *Teleoceras fossiger*, a complete skeleton of which has been mounted in the American Museum, and calls attention to some of its salient characters. A complete skeleton of *Coryphodon radians* is also described and figured. A study of this skeleton has revealed a number of new morphological features which have an important bearing on the restoration and classification of the animal.

The interesting *Phenacodus primævus* of Cope's collection has been removed from its original matrix and mounted. The bones are thus placed in their natural position and rendered available for detailed study.

"The Evolution of the Amblypoda" is a somewhat extended article and is not complete in this bulletin. The author discusses the origin of the Amblypoda and gives a synopsis of their evolution together with descriptions, relations and classification. The results of of Part I are well expressed in the author's own words, "First, the demonstration of a number of phyletic lines of Coryphodons. Second, that certain Coryphodons approach the Dinocerata in some structures as closely as they depart widely from them in others."

The reptile, *Camarasaurus*, is described from new material which shows characters hitherto unknown. The author points out its relations to *Brontosaurus*, with which it compares in size, and writes of its habits and peculiarities.

Dr. Wortman writes in detail of the Camelidae of North America. He reviews the known genera and species and adds the descriptions of several new ones. The descriptions of many of the old forms are amplified from new material. He makes a careful study of the Cameloids and gives their evolution as near as the incomplete knowledge of the forms will follow.

W. T. LEE.

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THE

JOURNAL OF GEOLOGY

MAY–JUNE, 1899

AMERICAN HOMOTAXIAL EQUIVALENTS OF THE ORIGINAL PERMIAN[1]

In this country the Permian question has long remained open. Its various phases are essentially the same today as they were forty years ago, when Permian faunas were first thought to be identified in the rocks of Kansas. For nearly a quarter of a century comparatively little information was added. Recently, however, active interest in the subject has been renewed, and new data have been acquired. With this revival of interest bob up also all the old questions. Concerning these there is as much difference of opinion as ever. Besides, new problems are presented.

In all of the discussions concerning the American Permian which have taken place in past years certain important facies of the theme have appeared to be wholly overlooked. In the newer considerations there is also a manifest tendency to pass over these very essential qualities. It seems pertinent, therefore, to consider briefly some of these phases of the subject. The following notes and comments are to be regarded as suggestive along the line indicated. No formal attempt is made to correlate in detail the terranes mentioned.

[1] Read before the Geological Society of America, December 28, 1898.

AMERICAN ROCKS ORIGINALLY REFERRED TO THE PERMIAN

Historical note.— Regarding the Permian in this country, three questions are prominently presented: (1) Should the Permian be recognized in America? (2) If so, what is the taxonomic rank of the succession of beds referred to it? (3) What are the upper and lower limits of the terrane so called? These questions are perfectly distinct, though they are usually considered together.

The introduction of Murchison's term Permian into the literature of American geology was due to Meek and Swallow, in 1858. The year previous, Hawn had collected, in central Kansas, the fossils identified by them as Permian forms. The beds from which these organic remains were taken form a part of an extensive sequence that extends in a broad belt from eastern Nebraska, through Kansas and Oklahoma, into central Texas. To this province the present notes refer.

After the first announcement of the discovery of supposed Permian fossils in this region, the subject was frequently discussed during a period of more than a dozen years. Meek, Swallow, Hawn, Shumard, Hayden, Newberry, Marcou, and Geinitz, made the principal contributions. Later White and Broadhead took up the subject to some extent. Recently Cragin and Prosser, in Kansas, and Cummins, in Texas, added much to our knowledge of the rocks in question.

The wholly disconnected character of the work of these authors is unfortunate. Except in a general way, is has been, heretofore, impossible to make any satisfactory comparisons between the different parts of the province. Only recently has any relationship been established between the results obtained by the various explorers of this region. Prosser has been chiefly instrumental in giving us something tangible to work upon. In connection with his own investigations, he has made a special effort to bring some of the earlier acquired results into close correspondence. The upper part of so-called Permian in Kansas still remains rather uncertain as to its natural subdivisions, and its relations to other sections. The lower part and the underlying

"Upper Coal Measures" along the Missouri River, which may be regarded as the standard section, have been lately carefully correlated.

The recent work has been sufficient to give us a good idea of the general character of the deposits regarded as Permian, the stratigraphical succession in the different parts of the province, the range of many species of fossils, and an outline of the main subdivisions that it will be useful to recognize.

Character of deposits.—The beds of the Continental Interior basin that have been considered as Permian, or Permo-Carboniferous and Permian, consist of two heavy shales, separated by thick limestones. The total thickness in Kansas is probably about 2000 feet; in Texas perhaps double this figure.

The lower beds are almost wholly made up of argillaceous and sandy shales, yellow, brown, green, and blue in color, and brown shaly sandstones. Occasionally occur thin, rather impure limestone bands, that carry abundant fossils. Near the bottom of the formation are some workable coals, associated with which is a characteristic flora.

The median number is composed largely of gray and buff limestones, often in thick layers, shaly limestones, and calcareous shales. The heavy limestones contain more or less chert in nodules and discontinuous bands. Abundant fossils are represented.

The upper part consists principally of gray, variegated, and red shales, and shaly limestones. Gypsum and salt deposits occur abundantly. Fossils occur only very sparingly.

In the main, the deposits indicate shallow waters, in strong contrast to the thalassic conditions that prevailed previously in the same regions. The sediments were laid down largely in closed basins, which finally become altogether dry.

General geological section.—In Kansas the general succession, as made out by Prosser and Cragin, is about as follows :

SECTION OF UPPER CARBONIFEROUS TERRANES OF KANSAS

Terrane	Thickness	Character
Kiger shales	210	Shales and sandstones, red chiefly (Upper "Red Beds"), with some gypsum, and thin dolomitic layers.
Cave Creek gypsum	40	Gypsum, massive, with some red shale.
Salt Fork shales	1000	Shales, and shaly sandstones, red (Lower "Red Beds"), with rock-salt and gypsum.
Wellington shales	350	Shales (lower salt measures), variously colored, gray predominating below, and gypsum.
Marion shaly limestones	150	Limestones chiefly, gray and buff, thinly bedded.
Chase limestones	250	Limestones, heavily bedded, much chert, and calcareous shales.
Neosho shales	140	Shales, yellow, green, and brown, with few thin limestone bands.
Cottonwood limestone	10	Limestone, fusuline, buff.
Wabaunsee shales	550	Shales, sandy, argillaceous, with a few thin coal seams.

Relations of Texas section.—In northern and central Texas the beds called Permian are well developed. Cummins separates the succession into three parts, which he terms the Wichita, the Clear Fork, and the Double Mountain, each being regarded about 2000 feet thick. According to this author, the section of the Paleozoic above the lower Carboniferous is:

CARBONIFEROUS TERRANES OF NORTHERN TEXAS

Terrane	Thickness	Character
Double Mountain	2075	Shales, red, sandy, often saline, with some earthy limestones, and much gypsum.
Clear Fork	1975	Limestones, and calcareous reddish shales, some sandstone.
Wichita	1800	Shales and sandstones, and some conglomerates.
Albany	Wanting.	Limestones.
Cisco	840	Shales, with coal beds.
Canyon	930	Limestones, with shales.
Strawn	950	Shales and shaly sandstones.
Millsap	1000	Shales, with coal beds, and shaly sandstones.
Lower Carboniferous		

Just what parallelism should be instituted between the Texas and Kansas beds is not yet quite clear. The apparent enormous

development of the beds in question in Texas as compared with those north of the Wichita range, and the meager information, of an exact kind, regarding the former, make any attempt at correlation little short of guesswork. However, White's fossils, collected in the upper Wichita and lower Clear Fork, indicate an horizon near the Plattsmouth beds of Nebraska. The Albany seems to be very nearly equivalent to the Missourian series below the horizon just mentioned. The Double Mountain beds are, in a broad way, manifestly approximately equivalent to Cragin's Cimarron series. This leaves a considerable part of the Clear Fork beds representing the Chase and Marion of Kansas. There are in Texas indications of an unconformity at the base of the Clear Fork. Should this prove true, as now seems probable, it amply accounts for a number of hitherto inexplicable phenomena connected with the Kansas rocks, above the main limestones of the Missourian.

Organic remains.—It is unfortunate that, with all the advantages that the various workers in the so-called Permian have had, the information regarding the faunas is so meager. Fossils are abundant, at least up to the middle of Prosser's Marion. Such as have been recorded present some interesting phases.

It cannot be gathered from the discussions concerning the fossils found in the Upper Paleozoic west of the Missouri River, in Kansas and Nebraska, just what should be considered the typical "Permian" fauna. The appearance of abundant lamellibranchs and the disappearance of brachiopods seem, as noted elsewhere, to be the most notable features to which attention has been called. Geinitz, considering the fossils found in the Nebraska beds, which he referred to the Dyas, had before him both types. These strata are now known to be partly immediately below the Wabaunsee and partly the very base of the latter. Geinitz did not misinterpret their position so badly as Meek and others would have us believe. His comparisons were made with European standards, and if such comparisons can have any value at all they indicate a degree of acumen on the part of the German paleontologist that few Americans credit him.

Meek's exhaustive criticism of Geinitz's work on the Nebraska faunas, and his other papers on the same subject, appear to be largely misinterpreted by later writers. So far as I am able to find out, Meek's efforts were not directed so much against the view of the Permian age of the Plattsmouth beds as they were to emphasize the fact that the faunas followed one another uninterruptedly from the "Upper Coal Measures" up to the "Red Beds." He was unable to see how a "new and distinct system" could be represented in such a perfectly continuous sequence.

The case of Meek and Swallow is different. It was, after all, a mere quibbling about unimportant details. With all their bitter controversies, their views were not very far removed from each other. Their subdivisions were practically the same. Only different names were employed. Swallow regarded the Paleozoic section above (approximately) the Cottonwood limestone, as divided into Lower Permian and Upper Permian. Meek, selecting dividing horizons slightly different, called the one Permo-Carboniferous and the other Permian. Both agreed in the upper member being Permian. Regarding the lower member, Swallow thought Permian fossils predominated; Meek considered species of the Upper Coal Measures more abundant. Neither seems to have presented any decisive proofs one way or the other.

Prosser's late classification of the central Kansas rocks claims to be based upon the faunas. The subdivisions are properly given special geographic names, but the division lines are very nearly the same as those selected by the earlier writers. The faunal evidence, as Prosser has set it forth in detail, appears to oppose, rather than to support, the conclusions he has drawn.

Range of fossils.—In all the faunal considerations that relate to the Upper Paleozoic of Kansas, the rapid disappearance of the brachiopod fauna "characteristic of the Upper Coal Measures," and its replacement by a "Permian" lamellibranch fauna, is pointed out as very significant. Such a comparison is hardly justifiable. The two cannot be thus contrasted any more than a fauna with a flora. They have no common points of relationship. The appearance of the latter in place of the former indicates a

change in physical conditions, but in this case nothing more. Similar and even more marked changes occur at a hundred different horizons in the Carboniferous lower down. When shallow waters prevailed, lamellibranch and gasteropod faunas occupied the areas. When pelagic conditions occurred, the occupants of the district were chiefly brachiopods. The latter moved in as the former moved out. Comparisons of faunas of different classes avail little; they must be of the same class if tangible results are to be expected.

In drawing conclusions regarding the fossils of the beds that have been referred to the Permian and the Permo-Carboniferous, the utmost caution is imperative. The terranes have been only very imperfectly and very unequally explored. Comparisons of faunas have been largely between zoölogical groups of different classes. Many of the beds in the general vertical section are understood only in a vague way. There are long intervals about which nothing either stratigraphically or faunally is known. With a few isolated exceptions, organic remains have yet been found only in the lower half of the succession. Fossiliferous beds reach, according to our present knowledge, only up to the middle of the Marion. In Texas the "Permian" fossils described by White and Cope were from the Wichita and Lower Clear Fork beds.

Taking the fossils, the horizons of which are definitely known, and as chiefly determined by Prosser, fifty-two species are recorded from the Wabaunsee. Of these only two new ones occur in the Cottonwood. In the Neosho following, one third of the twenty-one species noted are not reported from the lower beds; they are lamellibranchs. In the Chase eleven of the thirty-three species appear for the first time. The Marion contains fewer species, but they are forms occurring at lower horizons. The principal brachiopods run through the whole sequence.

THE ORIGINAL PERMIAN

Historical statement.—The Upper Paleozoic rocks occurring along the western flanks of the Urals, in eastern Russia, in

Europe, were thought by Murchison to constitute a distinct system, equal in rank to Carboniferous and Silurian. He named it, in 1841, after the ancient kingdom of Perm. Since that time much has been learned regarding this great terrane in the Russian provinces. Numerous comparisons have also been made with supposed equivalents in other parts of the world.

A notable fact regarding the Russian Paleozoic rocks above the Devonian is that in nearly every respect they are very similar to those forming the same part of the general geological section developed in the Mississippi Valley. The original Permian presents almost the identical features that do the beds so called in Kansas and Texas. And, strangely enough, the identical questions that have arisen in this country are bones of contention among Russian geologists.

Those who took part in the long excursions in eastern, central, and southern Russia before and after the sessions of the Seventh International Congress of Geologists, held in St. Petersburg in August 1897, had ample opportunity to study the original Permian under the most favorable circumstances. Under the personal guidance of Messrs. Karpinsky, Tschernyschew, Pavlov, Amalilsky, and Nikitin, especially, the typical and critical sections were examined and the fossils of the various horizons collected. With the aid of the official maps, such literature of the region as was at hand, and the explanations offered by the geologists mentioned, who with others had worked in the district and were well acquainted with the details, an unusually good idea of the Russian Permian was obtained.

To those from America, who were especially interested in the Carboniferous and Permian, this experience furnished much desired information. The similarity of the deposits, of their faunas, and of the questions concerning them, in the Russia and Mississippi provinces, seems to make some comparison of their features worthy of formulation. The bearing that a direct knowledge of the former has upon the latter will certainly tend to make our own problems easier of solution.

Distributions of the terranes.—The Carboniferous and Permian

rocks of Russia extend from the Arctic Ocean to the Black Sea — a distance of 1500 miles — and from the Urals westward a distance of 1200 miles. In the central and southern parts of the area is a thin covering of Cretaceous and Tertiary deposits. This vast basin, with its nearly horizontal strata, is comparable to our own Carboniferous basin of the Mississippi valley. In the latter region the lower portion of the sequence — or Coal Measures — predominates. In Russia the upper part, or Permian, forms the surface in most of the region.

Around the margins of the great basin, especially on the west and east sides, the Carboniferous is well developed. The lower Carboniferous, made up of limestones, is well displayed, lying immediately upon the Devonian. Relatively speaking, the Coal Measures are not very well represented, though the southern coal field, or Donetz basin, covers 1200 to 1500 square miles, and the central field, or Toula basin, has about the same area. On the flanks of the Urals some coal is also found.

The most typical sections of the Permian are in the Kama River Valley. The great Volga Valley, above Samara, is occupied chiefly by the so-called Permo-Trias.

Nature of the rocks.—The beds that are called Permo-Carboniferous, Permian, and Permo-Trias, which occur in the Kama River Valley present the most typical phases of Murchison's "system." The whole succession is tripartite. Shales, sandstones, and marls are separated medially by heavy dolomitic limestones.

The lower member consists of argillaceous and sandy shales, shaly sandstones, marls, and some impure limestones. Sometimes conglomerates are present. Abundant fossils are represented. Upwards of 300 species have been listed. A distinctive flora is also present.

The median terrane is made up chiefly of massive dolomitic limestones, separated by calcareous shales. It forms a striking contrast to the beds above and below.

The upper member is formed of variegated argillaceous and sandy shales, brown shaly sandstones, some of which are copper-bearing, marls, and occasionally thin limestone bands. Gypsum

is also frequently disseminated. The inferior portion is fossiliferous. Above this part come other shales, marls, and sandstones, almost destitute of fossils. They are thought by some authors to be Triassic.

The passage from the prominent marine phase of the Uralian Carboniferous to the subsequent shallow-water conditions is remarkable. The same closed basin depositions are as noteworthy as in the case of the American.

General section.—The Paleozoic beds above the strictly marine Carboniferous, as made out in the Ural region, are grouped by the Russian geologists in the following way:

UPPERMOST PALEOZOIC TERRANES OF EASTERN RUSSIA

Terrane	Symbol	Character
Tartaran	PT or P_3	Shales and marls, "Red Beds," very few fossils.
Zechstein (in part)	P_2	Marls, limestones, and sandstones.
———	P_b	Sandstones, shales, and marls with nodular limestones).
———	CP_c	Dolomitic limestones (base of Murchison's Permian).
Artinsk	CP_g	Shales, shaly sandstones. This and next terrane above are called Permo-Carboniferous.
———	C_3	Limestones.

Faunas represented.—The so-called true Carboniferous of the Urals is made up almost entirely of limestones. The highest member symbolized by the Russian geologists, C_3, contains a prolific fauna, which, while chiefly brachiopodous, has also a good representation of corals, some lamellibranchs, and fusulinæ.

Following, are the transition faunas to the Permian, according to the Russians, and by them called Permo-Carboniferous. The two members which comprise it contain, as pointed out by Tschernyschew, very nearly the same organic forms, consisting largely of lamellibranchs, gasteropods, and brachiopods. The lower terrane, termed the Artinsk, is notable for the ammonites that are found in it, which the author just mentioned compares with those lately found in the Texas Permian. The upper

terrane (CP_c), made up of dolomitic limestones largely, is the basal number of Murchison's original Permian.

The bottom terranes of the Permian, as now recognized by the members of the Russian geological survey, present a great paucity of fossils. The forms are chiefly lamellibranchs, yet in some layers are fragmentary plants.

The median part of the Permian carries what has been regarded as the typical German Zechstein fauna.

About the upper terrane there is much dispute as to age. The Russian geologists are about equally divided. Amalitzky considers it Permian. By others it is regarded as Triassic. Fossils occur rarely. Those found are chiefly lamellibranchs.

Base of Murchison's Permian.—As already noted incidentally, the lower limit of the original Permian, as established by Murchison in 1841, is the bottom of the dolomitic limestone immediately overlying what is called the Artinsk terrane. The geologists who have worked in the region place this line in the middle of the Permo-Carboniferous. The succession of strata and the sequence of faunas are continuous from the Carboniferous to the Permian. The transition is so gradual that it appears impossible to locate a satisfactory line of division between the two. The conditions are identical with those that we have encountered in this country, and, following our example, the Russians have adopted our term—Permo-Carboniferous.

While the adoption of such a course emphasizes the transitionary character of the faunal sequence, it complicates, rather than simplifies, matters. Two important divisional phases are recognized, both of which are as vague and unnatural as the one that this plan aims to obviate. On all other than faunal grounds, Murchison's lower limiting horizon of the Permian is the most satisfactory and perhaps also the most natural.

COMPARISON OF THE RUSSIA AND MISSISSIPPI VALLEY CARBONIFEROUS

Stratigraphic parallelism.—In Russia and in the Mississippi valley the general geological sections of the upper Paleozoic

are remarkably alike. The basins occupied by these rocks are very nearly of the same size. As already stated in the first-mentioned area, the Permian very greatly predominates as the surface rock. In the last-named, the coal measures. The Carboniferous of Russia presents two very distinct aspects—a thalassic facies, occurring on the western flanks of the Urals, and made up of limestones chiefly; and a shallow water or littoral phase, that is coal bearing, and that is best developed in the southern and western parts of the great area, principally in the Donetz and Toula basins.

COMPARISON OF GENERAL SECTIONS

Russia	Character of Terranes	Mississippi Valley
Tartaran, Permo-Trias, or Upper Permian, P_3	Shales and marls, red and variegated, shaly sandstones; fossils rare; "Red Beds"	Cimarron Series
Middle Permian, P_2	Limestones, some dolomitic, separated by calcareous marl	(Marion li.) } Series
Lower Permian. P_1–b	Shales (only 200 feet thick in Kama Valley)	——— ? } Series
Upper Permo-Carboniferous (base of original Permian) CPc.	Limestone, heavy dolomitic	(Chase li.) } Series
Artinsk, CP.	Shales, sandstones, some thin limestones	(Neosho) (Cottonwood) (Wabaunsee) } Series
Upper Carboniferous, C_3	Limestones and shales, highly fossiliferous	Missourian Series
Moscouan, Middle Carboniferous, C_2	Shales, sandstones, thin lime stones, coal-bearing	Des Moines Series
Lower Carboniferous, C_1	Limestones chiefly, some shale and sandstone	Mississippian Series

In the consideration of a theme like the present one, it is recognized at the outset, that comparisons of terranes of different geological provinces involves no necessary exact synchrony, except through absolute physical means of correlation. Such a standard, independent of intrinsic features of the terranes themselves, is not yet formulated for widely separated districts. The shortcomings of the common fossil criteria, in any other than the most general way and in the absence of something better, are well known. Any agreement of biotic features in stratigraphic successions distantly removed from one another are looked upon, so far as indicating simultaneous origin, only as happy accidents. Instead of furnishing proofs of time equivalency, it suggests for similar faunas only likeness of conditions, irrespective of time. Such faunal facies are only representative. They are merely homotaxial.

Any similarity of lithological succession is likewise accidental. The same is manifestly true of any other agreement of intrinsic features.

Nevertheless, a comparison of general geological sections in provinces so widely separated as the two under consideration, and so wholly distinct from each other in their origin, can be made not only suggestive but very profitable. The same problems for solution arise in both districts. The naturally different manner of treatment is mutually helpful in the solution of the various difficulties that are presented. Misconceptions regarding each are dispelled. Greater independence in the consideration of succession is established.

The most remarkable fact connected with the Russian section of the Upper Paleozoic and that of Kansas is that the two should be capable of any comparison at all. While the two differ much in stratigraphic, lithological, and biotic details, in general all three classes of characters present a very similar sequence.

Lithological features.—In the Russian and American Permian provinces, the field appearance of the rocks is very strikingly alike. This is particularly true of the upper half of the two sections. The general features are lost in the local examinations.

In the Russian district one finds it difficult to imagine that he is not wandering through some part of Kansas. Only the presence of the Russian peasant, or sudden contact with a village of the steppes dispels the illusion. In the Upper Paleozoic the aspects of the limestones and shales, their succession and expression are the same on the banks of the Volga or Kama as they are in the bluffs of the Missouri or Kansas rivers.

The original Permian strata are indistinguishable, lithologically, from the so-called Permian of Kansas. In both there are the same gray and variegated sandy shales and marls, passing locally into sandstones, that are often copper-bearing. Occasionally there are present thin bands and beds of buff earthy limestone. Gypsum is abundantly developed in beds and interspersed everywhere through the rocks. Saline shales are of not infrequent occurrence. On both continents all these pass upward into "Red Beds," that are almost destitute of fossils. Whether the last mentioned strata are Permian or Triassic is still, in both countries, an open question.

Range of faunas.—The succession of faunas appears to be essentially the same in the Russian Carboniferous and Permian as in the Mississippi valley. The composition of each of the faunas is also strikingly comparable. The most noteworthy feature of the organic remains, viewed as a whole, is the gradual replacement of a purely marine type by a shore and brackish water phase, as the change from open sea to closed water conditions took place, and finally to those in which life could not exist.

The most prominent characteristic of the biotic change from a Carboniferous phase to a Permian one seems to be the replacement of a predominantly brachiopod fauna by one in which lamellibranchs formed the preponderant element. This change has not, however, the deep significance usually attached to it. There are many other factors that appear to be largely or entirely overlooked. Faunal considerations should dwell more particularly on some of these other features, rather than upon a detailed tabulation of specific sequence.

The chronologic equivalence and comparison of rocks being universally based almost wholly upon the standard of the fossils is at best a very uncertain criterion. In the case of the Permian this uncertainty has been increased tenfold on account of the peculiar treatment that the fossils have received. The investigation of the biotic characteristics of the Upper Paleozoic has been very unsymmetrically developed and very unequally carried out. This is true in both Russia and America. From the published material no comparison of faunas is really possible; that is, in the sense that modern work demands. This chaotic condition of affairs is not anomalous. It occurs with many other faunas from many different horizons. In the present instance it is merely accentuated by a combination of accidental circumstances.

A most noteworthy factor is the extreme local character of the well known, published information. A single American instance suffices for illustration. Our best knowledge of the faunas of the Upper Coal Measures (Missourian) is derived almost entirely from a single horizon, at the single locality of Plattsmouth, Nebraska. This place has been made classic by Geinitz and Meek. All faunal comparisons, made through secondary means, of the rocks of the Mississippi valley above the lower productive Coal Measures (Des Moines) can take into consideration only the little pamphlet of Geinitz and the thin volume of Meek. Much has been made of this horizon by Waagen, Tschernyschew and other foreign paleontologists. Our American workers among the fossils have also depended largely upon the same sources of information.

As a matter of fact, the fauna of the Plattsmouth is characteristic not of a single, insignificant terrane, but of the entire Missourian series, and upward almost to the limits of the fossiliferous zones of the upper Paleozoic of the region — that is to the Marion. To be sure, as to numbers, the various species are differently represented at the several horizons; some forms are not reported yet from this level or that one; others appear that are not recorded from the Plattsmouth beds; yet, for a region in which no effort has ever been made to exploit systematically

the various horizons, and for a great succession of abundantly fossiliferous beds in which our published information is meager in the extreme, it is remarkable through how great a vertical interval the main characteristics of this Plattsmouth fauna are preserved.

The Plattsmouth remains are referred to as forming a characteristic maritime fauna. So it is, but it is identically the same fauna that is found at half a hundred other horizons between the lower coal measures and the "Red Beds." Whenever the heavy limestones occur the same groups of brachiopods appear. Whenever the more argillaceous shales are found the same lamellibranchs begin to predominate. Where the sandstone and coal-bearing shales are prominently developed coal plants and peculiar lamellibranchs and gasteropods are in evidence. These distinct faunas succeed one another in the same vertical section. They are repeated scores of times. Pretty nearly the same phenomena appear to obtain in the great Carboniferous basin of eastern Russia. In both regions the gradual replacement of the brachiopodous fauna by a "Permian" lamellibranch fauna follows the local change of open to closed sea conditions.

The Permian element of these faunas was merely a shallow water facies of the more typical Carboniferous fauna. It oscillated horizontally back and forth with each local change of bathymetric conditions. It was repeatedly intercalated between horizons carrying the greater thalassic phase. Meek's contention for the fauna of the Plattsmouth beds was for its identity with the fauna of the upper coal measures of the region. He was right. In his argument for the Permian character of the same fossils Geinitz was not wholly wrong. The point of vantage of each was merely slightly different. Could they have consulted more fully, they would have been no doubt soon in close agreement.

TAXONOMIC RANK OF THE PERMIAN

Principles of geological classification.—It is a well-known fact that the modern classifications of animals and plants are based primarily upon genetic relationship. A natural arrangement of

rock terranes is likewise genetic. It is strictly a function of cause and effect. It is only regarding the position of any particular component in a classification, that is subject to a difference of individual judgment. The taxonomic rank of a group may be subject to change as knowledge increases. Among organisms an advancement in rank is frequent. Families eventually attain the rank of orders; genera of families; smaller groups are classed as genera. The same is true of geological formations.

Recognizing, in the taxonomy of rock terranes, the five taxonomic ranks of group or assemblage, system, series, stage, and zone, as amply sufficient subdivisions, at least for all practical purposes, a succession of beds at first given only the rank of a stage may be subsequently advantageously raised to that of series. Stage is a local unit; while series is a provincial one; and system essentially universal.

In applying these principles to the Permian, the question resolves itself into two distinct phases: What should be considered the taxonomic rank of the original Permian? and What is the rank of the succession of beds in this country, referred to the Permian?

Taxonomic position of the Original Permian. — Regarding the rank of the so-called Permian in general, there is much difference of opinion. The older school of geologists, that is permeated thoroughly with the idea that fossil faunas are exactly recognizable the world around, and that we can by them and without effort synchronize the provincial rock successions of different continents, is inclined to recognize in the Permian a universal extension, and to assign it a rank of a system, comparable to Carboniferous or Devonian. The more modern school of geological investigators, that tests classification and correlation by more that a single standard and that is seeking exact results and genetic relationships, would consider the original Permian as a provincial succession, and give it the rank of a series, under the more comprehensive system of the Carboniferous.

If one were to attempt anew to classify the upper Paleozoic deposits of eastern Russia, following the criteria that we have adopted in this country, he would have no hesitancy in assigning to the Permian of that region the rank of a series, and make it a subdivision of the Carboniferous. There is, however, a strong possibility of three or more well marked members being recognized in the original Permian succession, the rank of each of which is certainly higher than that of stage. The uppermost, or Tartaran, division is an example. This may prove to be Triassic in age. The inevitable tendency to advance the rank of such divisions, with the progress of knowledge regarding them, makes it almost certain that the divisions mentioned as having the same rank as the Tartaran, will be eventually regarded as series. Permian will then have to be either advanced to the rank of system, or to a new order intermediate between system and series. The latter course is manifestly not only unnecessary, but undesirable, and according to our present principles, unnatural. The former course is of very doubtful utility, and not feasible on account of the almost universal apathy on part of geologists to increase the present number of recognized systems. When the time comes to regard the present divisions of the original Permian as distinct series, Murchison's term will be, in all probability, quietly dropped. It would appear then, that all things considered, the original Permian can be at best only regarded as a series, and a part of the Carboniferous. The term like many others will then only have an historical significance.

Subdivisions of the so-called Permian beds of the Mississippi valley.— Most Americans, who are at all familiar with the subject, are inclined to regard the beds referred to the Permian as forming a main division of the Carboniferous. The text-books, as a rule, express this view also, and subdivide the Carboniferous system into three parts, the Sub- or Lower Carboniferous, the Coal Measures, and the Permian. With the recent general adoption of the more systematic method of stratigraphic nomenclature and a tendency to impart technical exactness by the use of geographic names, the first named division in this region has

been called the Mississippian series. In its broadest sense the so-called Lower, or Productive Coal Measures finds satisfactory expression in the Des Moines series. For the "Upper Coal Measures" nearly to the usually selected horizon for the base of the Permo-Carboniferous, Missourian has been suggested as a serial name.

The uppermost division of the Paleozoic of the region, the part widely designated as the "Red Beds," has received the title of Cimarron series. It appears to form a tolerably compact sequence, though there is still some dispute as to its exact geological age. Between the Cimarron series and the Missourian series are two other terranes that are well defined. One is composed of the Chase and Marion of Prosser, in part, and the other of the Wabaunsee, Cottonwood, and Neosho.

Should some such subdivision of the Upper Paleozoic be found applicable over the larger portion of the Mississippi basin, as now seems likely, the use of Permian and Permo-Carboniferous will be rapidly discontinued, or will be invoked only in historical reference.

RELATIONS OF "UPPER PERMIAN" TO TRIASSIC

There is little satisfactory data upon which to correlate the beds called Triassic in eastern United States with other regions. The determinations appear to have been largely made upon lithological grounds and plant remains. There is no real physical relation between the Triassic, or Newark in the main, of the Atlantic border, and the Triassic of the region lying to the east of the Rocky Mountains.

The "Red Beds" of Kansas and Texas are thought by some writers to be Triassic in age; by others Permian. In the almost total absence of fossils in these beds, the lithological characters and general red coloration have been resorted to as criteria. Of late the question has been taken up anew. Prosser has been led to believe that the greater part of the Kansas "Red Beds" are Triassic. Williston, from even more reliable data, is inclined to regard the lower part at least as Paleozoic.

The question bids fair to remain unsettled, until some data more tangible and critical are obtained. The deposits of the Triassic of this region were laid down nearly under the same conditions as some of the so-called Permian, The beds appear to have been formed without interruption of sedimentation in enclosed basins. Vertebrate and plant remains are to be expected to form the prevailing forms of life. They cannot be very well compared with marine invertebrate faunas. Such a comparison would, if attempted, prove unprofitable. The clue must be evidently sought in physical criteria, and in the stratigraphy of the region. Sufficient work in this direction has not been done. The exact line of demarcation between the two must therefore remain undetermined for the present.

While this question is brought up at this time with the full knowledge that it has little bearing upon the main theme here presented, it is alluded to for the express reason that the same problem that has come up in connection with the deposits with which we have been comparing the American so-called Permian, has troubled the Russian geologists in their study of the original Permian area. Their Tartaran "Red Beds" are as perplexing as ours; and the opinions as to age are equally divided. Several writers, notably Karpinsky, Nikitin, and Tschernyschew are of the opinion that these deposits were laid down in isolated inclosed brackish water lakes, that continued to exist into the Triassic period. On the other hand, another group of equally shrewd observers, headed by Amalitzky, Schtukenberg, Netchaiev, and Krotov, regard all of these beds as Paleozoic. For all practical purposes the views of the last mentioned workers appear most reasonable.

In this country, the conditions appear identical with the Russian. Amalitzky's idea is equally applicable here, unless it is shown that marked and widespread unconformaties exist near or at the top of the American "Red Beds" and that the undoubted Triassic can be thus clearly separated.

RECAPITULATION

Returning to the original questions, propounded at the beginning, all available evidence appears to indicate :

1. That while we have in America a great succession of deposits identical in all essential respects to the original Permian of Russia, the two great basins merely had similar histories that are not necessarily connected, and doubtless were wholly independent of each other and unrelated ; that the Russian Permian constitutes a geological province by itself ; and that therefore the term Permian should not be used as a technically exact term in connection with the Mississippi valley deposits.

2. That Permian, as originally proposed, applies to a provincial series, and according to our usual standard has at best a taxonomic rank below that of system. Also, in view of the possible elevation of its main subdivisions to the rank of series, the term will have no position in the general scheme of classification. It will be no doubt eventually dropped altogether. The various series belonging to the succession and now having lower rank, will be considered main subdivisions of the Carboniferous system. In this country the same plan has been already proposed.

3. That, with the solution given to the second question, it is unnecessary to attempt to locate the limits of the so-called Permian in this country. The divisional lines of the series comprised in the typical American section in Kansas are already well defined, with the possible exception of that of the uppermost member.

CHARLES R. KEYES.

CORRELATION OF THE CARBONIFEROUS ROCKS OF NEBRASKA WITH THOSE OF KANSAS

In the Journal of Geology the writer published in 1897 an article on the "Comparison of the Carboniferous and Permian Formations of Nebraska and Kansas"[1] in which he correlated the formations found in Nemaha, Otoe, and Cass counties of southeastern Nebraska with those of eastern central Kansas. At that time comparatively little work in areal geology had been done in northeastern Kansas, the Cottonwood limestone being the only formation that had been even approximately traced from the Kansas River north to Nebraska.[2]

The correlation of the formations in the above paper was based entirely upon their lithologic, stratigraphic, and faunal characters, for the writer did not have an opportunity to trace the distribution of any of the formations to the north of the Kansas River or to study the geology of the region between that river and Nemaha county, Neb. The rocks to the west of the Missouri River, covering the eastern part of Nemaha, Otoe, and Cass counties, were correlated with the Wabaunsee[3] forma-

[1] *Op. cit.*, Vol. V, No. 1, p. 16, and No. 2, p. 148.

[2] See "A reconnoissance geologic map of Kansas," in the Univ. Geol. Surv. Kans., Vol. I, 1896, Pl. XXXI.

[3] Since this article was written a paper has been published by Dr. Charles R. Keyes, in which he substitutes the name "Atchison Shales" for the Wabaunsee formation (Am. Geologist, Vol. XXIII, pp. 304, 309, 310.) The claim for the priority of Atchison shales rests upon the fact that, in 1873, Professor G. C. Broadhead published, under the general title of "Upper Coal Measures," the following heading for a section of the Upper Carboniferous rocks: "General vertical section of Upper Coal Measure rocks below the Atchison county group" (Geol. Surv. Mo., Preliminary Rep. Iron ores and coal fields, 1872, Part II, Geol. Northwestern Mo., chap. iv, p. 88.) In this chapter there is no description of the "Atchison county group" or further reference to it. Chapter xiv of the report by Professor Broadhead is devoted to a description of the geology of Atchison county" (*ibid.*, pp. 376–388); but there is no mention of "Atchison county group" in the entire account, and it is stated under the heading of the "Upper Carboniferous" that "the rocks of this county belong to the

tion of Kansas; while a massive *Fusulina* limestone west of Auburn, Nemaha county, was regarded as the Cottonwood limestone.

It remained, however, to trace these formations from the Kansas River Valley into Nebraska in order to fully demonstrate the accuracy of the above correlations. Fortunately the recent areal work of the University Geological Survey of Kansas has nearly completed this part of the proof. As the classification of the formations of southeastern Nebraska has an important bearing upon the Permian question of Nebraska and Kansas a synopsis of the results of this work will be of interest. During the summer of 1898, Mr. J. W. Beede of the University of Kansas, traced the Burlingame limestone from the Kansas River,

upper part of the Upper Coal series, and include limestones, sandstones, and shales, amounting to about 180 feet in thickness" (*ibid.*, p. 379). Dr. Keyes gives the thickness of the Atchison shales as 500 feet on the Missouri River, and describes the stage as composed mainly of shales with a stratum of coal near the base (*op. cit.*, p. 310). In Kansas the Wabaunsee formation is composed of massive limestones separated by calcareous, argillaceous, and arenaceous shales. (See the writer's description of the formation in JOUR. GEOL., Vol. III, pp. 688–697.)

The only other reference to the Atchison county group in Professor Broadhead's papers, known to the writer, is in his article on the "Coal Measures of Missouri," where he revised and quoted the section from the 1872 report, with this introductory sentence: "The following is a vertical section of the Coal Measures below the Atchison county beds" (Mo. Geol. Surv., Vol. VIII, 1895, p. 360). On page 377 is a brief description of the highest rocks in the state, which are said to occur in "Atchison and the northern part of Holt county," but as far as a formation name is concerned, they are put under what is termed "Group A," and there is no mention of Atchison county group or beds.

In view of the above facts it does not appear to the writer, in the first place, that the name "Atchison county group," used by Professor Broadhead in 1873, was ever defined as the name of a formation; and, secondly, that the name "Atchison shales," proposed by Dr. Keyes in 1899, is not entitled to be substituted for the Wabaunsee formation described by Prosser in 1895.

The writer finds that the above is essentially the opinion of other geologists familiar with questions of this character. It is clearly stated in the following letter from one of the members of the International Commission on Stratigraphic classification: "I do not possibly see how the use of the term in the manner described could be regarded as a formation name. Many such indefinite uses of local names are found scattered everywhere through geological literature, and if we are to go back in every instance to such a usage, few I fear of our formation names would stand. The name to my mind must be applied to a definite series of deposits with clearly defined limits, if it is to have any formational significance."

near Topeka, to the Nebraska line.[1] The Burlingame limestone was named and described by Mr. Hall, in 1896, from outcrops near Burlingame, Kansas,[2] and since then, through the efforts of Professor Haworth and Messrs. Adams, Bennett, and Beede, its outcrop has been traced[3] from Nebraska across the state to Oklahoma. In its stratigraphic position this limestone is now regarded as forming the basal subdivision of the Wabaunsee formation, which is thus clearly marked, as the limestone forms a prominent escarpment along the greater part of the line of its outcrop across the state. The lower part of the Wabaunsee formation was described from exposures along Mill Creek and the Kansas River between McFarland and Topeka, its base being marked by the Silver Lake coal. At that time the Silver Lake coal, exposed in the Kansas River bluffs west of Topeka, was supposed to belong in the same horizon as the Osage coal and to form a zone capable of being traced for two thirds or more of the distance across the state.[4] Mr. Beede has shown later that the Topeka coal, 125 feet below the Silver Lake coal, is the Osage coal,[5] and since the higher coal is not conspicuous south of the Kansas River it does not serve as a continuous line of division for the base of the Wabaunsee formation. Along the Kansas River, however, the Burlingame limestone[6] is only from 15 to 35 feet above the Silver Lake coal, and as this limestone forms a marked outcrop extending entirely across the state, it serves as a definite line for the base of the Wabaunsee formation, as has been suggested by Professor Haworth.[7]

[1] Kans. Univ. Quar., Vol. VII, Series A, Oct., 1898, p. 232. A more detailed account will appear in Vol. XVI of the Transactions of the Kansas Academy of Science.

[2] Univ. Geol. Surv. Kans., Vol. I, p. 105.

[3] See "A map showing limestone outcroppings," by ERASMUS HAWORTH, Vol. III, Univ. Geol. Surv. Kans., 1898, Pl. VII.

[4] Jour. Geol., Vol. III, 1895, p. 689 and f. n. 1.

[5] Trans. Kans. Acad. Science, Vol. XV, 1898, p. 30.

[6] MR. BEEDE, in his paper on "The Stratigraphy of Shawnee County" used Swallow's name of Stanton limestone (*ibid*, p. 30).

[7] Univ. Geol. Surv. Kans., Vol. III, p. 105.

As already stated, Mr. Beede has traced the Burlingame limestone from near Topeka to the Nebraska line, where it is, apparently, exposed in the bluff on the northern side of the Great Nemaha River, nearly due north of Robinson, Kansas. At the base of the bluff, several feet below the limestone, coal has been mined which Mr. Beede thinks probably represents the Silver Lake coal, and his description of the stratigraphic position of other coal beds in northeastern Kansas strongly supports this correlation.[1]

On the Kansas River the Wabaunsee formation has a thickness of 500 feet, and this, apparently, agrees quite well with the thickness of the rocks included between the Burlingame limestone in southeastern Nebraska and the limestone west of Auburn, Nemaha county, which is considered to cap the formation and is correlated with the Cottonwood limestone. Mr. Beede states that it is but a short distance east of the exposure of Burlingame limestone and coal in the bluff of the Great Nemaha to the river's mouth, where Hayden saw the outcrop of coal and sandstone on the bank of the Missouri River.[2] This coal, according to Mr. Beede, "is without doubt the same coal that is mined on the north side of the Great Nemaha and, consequently, probably of the same horizon as the Silver Lake coal."[3]

This is an important correlation, for Meek was inclined to consider the outcrop at the mouth of the Great Nemaha as stratigraphically above the famous Nebraska City section, stating that: "I am inclined to believe this sandstone under the coal the same bed seen at Peru and Brownville, and at the base of the section at Aspinwall, though it may be another holding a lower position. If it is the same, there can be little doubt but the exposures here near Rulo hold a position in the series above the horizon of the Nebraska City section."[4] Mr. Beede has

[1] Kans. Univ. Quar., Vol. VII, p. 232, and the forthcoming Vol. XVI, Trans. Kans. Acad. Science.

[2] Final Rep. U. S. Geol. Surv. Nebraska and portions of Adjacent Territories, 1872, pp. 115 and 116.

[3] Trans. Kans. Acad. Science, Vol. XVI.

[4] Final Rep. U. S. Geol. Surv. Nebraska, etc., p. 116.

also studied the Nebraska City section and, although he has not traced the strata from the mouth of the Great Nemaha to that locality, still he says: "the rocks at Minersville [formerly Otoe City] and Nebraska City are just what we should expect if Meek's correlations were correct, as a comparison will show: At the base of the Nebraska City section are several layers of limestone, then, above, a thick bed of shales and sandstones, coal and limestone, then over 100 feet of shales which contain a second coal, and above this another limestone, which makes it agree in stratigraphic succession, as it does in fossils, with the Topeka section. Thus, considering the great care with which Meek did the work, we can but come to the conclusion that his correlation is probably correct.

"If the foregoing statements are correct, we are forced to the conclusion that the Nebraska City section of Meek, from the base of the lower limestone to the top of the Minersville section, corresponds to the Topeka section from the Topeka limestone nearly to the base of the Burlingame limestone."[1] While in another article, in discussing Meek's reference of the sandstone at the mouth of the Great Nemaha to a stratigraphic position above that of the Nebraska City section, he says: "If this be true, it throws the section at Nebraska City in the same general horizon with the Topeka-Osage coal, if it be not identical with it, and the limestone at the base of the section would then represent the Topeka limestone, or a part of it. While I have not been over the ground between Minersville and Rulo, Neb., I am of the opinion that this conclusion is correct."[2]

The writer is inclined to consider the conclusion of Mr. Beede regarding the age of the Nebraska City beds as correct; and if so the rocks composing this section are equivalent to the Topeka limestone and Osage shalesof the Kansas River section, which form the upper part of Professor Haworth's Shawnee formation of the Upper Coal Measures.[3] This correlation agrees

[1] Trans. Kans. Acad. Science, Vol. XVI.

[2] Kans. Univ. Quar., Vol. VII, Ser. A, pp. 232, 233.

[3] Univ. Geol. Surv. Kans. Vol. III. p. 94.

quite closely with my earlier one, for it was stated in that paper that: "The writer is not confident whether the Nebraska City beds should be referred to the upper part of the Missouri formation,[1] or to the Wabaunsee formation of the Missourian series. However, the faunal and lithologic characters of the beds near Nebraska City agree quite closely with those of the lower half of the Wabaunsee formation as shown along the Kansas River above Topeka, and so the writer refers them provisionally to it."[2]

The distribution of the carboniferous rocks in southeastern Nebraska has been given by Mr. N. H. Darton, on a "Preliminary Geologic Map of Nebraska,"[3] where they are represented under the legend of the "Cottonwood and Wabaunsee formations." On the same map, a part, at least, of the rocks mapped in the Big Blue valley as "Permian limestone" may be correlated with the Chase formation of Kansas.

It will be remembered that Marcou referred the Nebraska City beds to the Permian, and in this correlation he was supported by Geinitz, who described the fossils collected by Marcou, and strongly opposed by Meek, who referred the rocks to the Upper Coal Measures. This difference of opinion led to a sharp controversy, the essential features of which were noted in my former paper.[4] There is now no question but that Meek was correct in referring these rocks to the Coal Measures, as was noted in the writer's former paper, and is now stated by Mr. Beede.

It seems important, however, to again call attention to the fact that Meek in correlating these rocks along the Missouri River in southeastern Nebraska with the Upper Coal Measures

[1] At the time the above article was written I understood that Dr. Keyes intended to retain the above name for that division of the Missourian series next older than the Wabaunsee formation. It was not used, however, and now Professor Haworth's Shawnee formation includes that part of the series.

[2] JOUR. GEOL., Vol. V, p. 151.

[3] Nineteenth Ann. Rep. U. S. Geol. Surv., Pt. IV, Pl. LXXXII.

[4] *Op. cit.*, pp. 12–16.

did not intend to include the rocks in Kansas which he and Hayden had called Permian,[1] a fact which has been overlooked by some of the later writers in considering the rocks of this region or the Permian. This was stated clearly enough by Meek when he gave his views regarding the age of these rocks as follows: "[they] really belong entirely to the true Coal Measures; unless the division C [the upper fossiliferous one] at Nebraska City, and some apparently higher beds below there on the Missouri, may possibly belong to the horizon of an intermediate series between the Permian and Carboniferous, for which, in Kansas, Dr. Hayden and the writer proposed the name Permo-Carboniferous . . . . . It is true that in first announcing the existence of Permian rocks in Kansas, we also, upon the evidence of a few fossils from near Otoe and Nebraska Cities, resembling Permian forms, referred these beds to the Permian; but on afterwards finding that these fossils are there directly associated with a great preponderance of unquestionable Carboniferous species; and that there is also in Kansas a considerable thickness of rocks between the Permian and upper Coal Measures containing, along with comparatively few Permian types, numerous unmistakable Carboniferous forms, we abandoned the idea of including these Otoe and Nebraska City beds in the Permian. And all subsequent investigations have but served to convince us of the accuracy of the latter conclusion."[2] This view was explained more fully in Meek's Review of Geinitz, on the rocks and fossils of Nebraska, published in the November following his exploration there, in which, after describing a series of rocks occurring in Kansas, containing an extensive Coal Measure fauna, often mingled in the same beds with a few Permian types, he said: "In ascending several hundred feet higher in the series, we observed the Coal Measure forms gradually dropping off until at last, above a certain undefined horizon, with the exception of one or two of the latter,

[1] Trans. Albany Inst., Vol. IV, 1858, p. 76; Proc. Acad. Sci. Phil., Vol. XI, 1859, pp. 20. 21; and Am. Jour. Sci., 2d ser., Vol. XLIV, 1867, p. 37.

[2] Final Rep. U. S. Geol. Surv. Neb. etc., pp. 130, 131.

only Permian forms were observed. Although we regarded these upper beds as the true representatives of the Permian, we gave a section of the whole series, down so as to include a considerable thickness of beds below, with lists of fossils, showing the range of the various types, without drawing any line of demarkation, because we were satisfied nature had nowhere defined any abrupt physical or paleontological break here in the series,"[1] . . . . that is, that there is in this region [Kansas], a gradual shading off from an upper Coal Measure to a Permian fauna, through a considerable thickness of strata, forming a somewhat intermediate group, which we called the Permo-Carboniferous series ; also that there is no defined break between this intermediate series and the Permian above, or the Coal Measures below."[2]

It is also true that Hayden did not abandon the correlation of the highest Paleozoic rocks of Kansas with the Permian, for in July, 1867, he published some "Notes on the Geology of Kansas," in which he reviewed "Swallow's Preliminary Report of the Geological Survey of Kansas," not accepting his division of the Lower Permian as of true Permian age, and said: "As we ascend in the series, we find that, after going some distance above the supposed line of demarcation [Swallow's between the Lower Permian and Coal Measures] the Carboniferous species gradually begin to disappear, and the Permian types become rather more common, in particular beds, until we have ascended to a point near the horizon Professor Swallow makes the line between the Upper and Lower Permian, when we find we have almost completely lost sight of the familiar Carboniferous species, a few of which had continued on up to near this point, and see scarcely any but forms such as in Europe would be regarded as Permian types. There is no physical break here, however, nor *abrupt* change of fossils. Hence Meek and Hayden regarded the beds below the horizon down so far as to include most, if not nearly all, of Professor Swallow's Lower

[1] Am. Jour. Sci. 2d ser. Vol. XLIV, 1867, p. 334.

[2] *Ibid*, pp. 338–339.

Permian, as an intermediate connecting series between the Permian and Coal Measures which, if worthy of a distinct name at all from the latter, should be called Permo-Carboniferous, while the beds above they regarded alone as properly the equivalent of the true Permian of Europe.

The occurrence of a few types that would generally be regarded as Permian, along with numerous well-known Coal Measure species, far below the true Permian, only accords with facts observed in other formations in this country, where certain types evidently made their appearance here long before they are known to have appeared in Europe."[1] In discussing the rocks of Gage county, Nebraska, in the Final Report of 1872, Hayden also described a section on a small branch of the Big Blue River, near Beatrice, about which he wrote as follows: "Beds 1, 2, and 3 of the above section are undoubtedly of Permian or Permo-Carboniferous age, though they contain fossils common to both Permian and Carboniferous rocks. . . . . Bed 4 seems to form a sort of transition bed between the Permian[2] and Carboniferous [misprint for Cretaceous] formations."[3]

This later study of the rocks of southeastern Nebraska has made it possible for us to determine approximately how far below the base of Meek and Hayden's Kansas Permian the Nebraska City rocks occur, and this is perhaps its most important result. The line between the Permian and Permo-Carboniferous of Meek and Hayden was drawn at the top of No. 11 of their "General section of the rocks of [the] Kansas Valley;"[4] which, as I have shown, occurs about ninety feet below the top of the Chase formation.[5] Then, if we accept the correlation that

[1] *Ibid.*, p. 37. In this paper Hayden referred to notes which Meek had given him, stating that they "form the substance of this article," p. 321.

[2] It is not certain that the true Permian beds, as recognized in Kansas, extend northward into Nebraska, though thin beds may occur in some of the southern counties.

[3] Final Rep. U. S. Geol. Surv. Nebraska, etc., p. 28.

[4] Proc. Acad. Nat. Sci. Phil., Vol. XI, 1859, pp. 16 and 20.

[5] Jour. Geol., Vol. III, pp. 784, 797, 798.

the top of the Minersville-Nebraska City section is stratigraphically a little lower than the Burlingame limestone, we will find that on the Kansas River, between the base of this limestone and that of Meek and Hayden's Permian are the Wabaunsee, Cottonwood, and Neosho formations, together with the greater part of the Chase formation, having a total thickness of approximately 900 feet. When it is also considered that massive limestones constitute a considerable portion of these rocks it will be seen that there is a decided time interval between the Nebraska City rocks and those of Meek and Hayden's Permian in Kansas. Or, again, the thickness of the rocks between the base of the Burlingame limestone and the base of Swallow's Lower Permian along the Kansas River, or Meek and Hayden's Permo-Carboniferous, is approximately 525 feet.

The failure to note the difference in age and faunas between the rocks of the Nebraska City region, along the Missouri River, and those of the upper Kansas and lower Smoky Hill River valleys in Kansas has led to certain erroneous statements and conclusions. This is possibly the explanation for the statement of Professor Calvin in his contribution to "A symposium on the classification and nomenclature of geologic time-divisions," in which he says: "The greater part of the assemblage of strata called Permian by Prosser and the geologists of Kansas University contains precisely the same fauna as our Missourian or Upper Coal Measures, and if there is no better excuse for recognizing Permian in America than that afforded by the beds in question, then America has no Permian."[1] The rocks which I have correlated as Permian, but without expressing a positive opinion as to whether the division should rank as a distinct system or as the upper group of the Carboniferous system (using Dana's stratigraphic terms) are the Neosho, Chase, Marion, and Wellington formations and the Cimarron group or Red-beds. The line between the Permian and the Upper Coal Measures or Missourian group was drawn provisionally at the base of the Neosho formation;[2] because in the Neosho and

[1] Jour. Geol., Vol. VI, p. 353.

[2] *Ibid.*, Vol. III, pp. 795, 800.

Chase formations zones occur in which there are numerous specimens of a few species which belong to genera that in Europe are regarded as of Permian age ; but inter-stratified with these zones are others which contain numerous specimens of a considerable number of the Missourian species. The writer has already stated that "The Neosho and Chase formations are transitional from the Upper Coal Measures to the Permian as first defined by Murchison for Russia, and belong to the division which has generally been called Permo-Carboniferous in this country. In accordance with the views of the majority of present European geologists familiar with this problem it is probably better to include the Permo-Carboniferous rocks of Kansas in the Permian series."[1] The base of the Neosho formation is about 50 feet higher than the base of Swallow's Lower Permian or Meek and Hayden's Permo-Carboniferous ; and the top of the Chase formation is, approximately, 90 feet higher than the base of Meek and Hayden's Permian, or between 50 and 80 feet lower than the top of Swallow's Lower Permian. The thickness of the Neosho is 130 feet,[2] and that of the Chase 265 feet,[3] making a total thickness of 395 feet. Mr. Beede, who is describing the Carboniferous and Permian invertebrate faunas for the University Geological Survey of Kansas, writes me that "there is ample evidence for placing the division line between the Coal Measures and Permian where you have."

Succeeding the Chase is the Marion formation, with a thickness of from 300 to 400 feet.[4] The lower portion of the Marion contains a fair Lamellibranch fauna which, however, decreases until in its upper part very few species are found. The following thirteen species and one variety have been found in this formation, together with some other forms which as yet have only been doubtfully identified either specifically or generically, viz.: *Aviculopecten occidentalis* (Shum.) Meek, *Bakevellia parva* M. &

[1] JOUR. GEOL., Vol. III, pp. 795, 796.

[2] *Ibid.*, pp. 766, 799.

[3] *Ibid.*, pp. 773, 798.

[4] Univ. Geol. Surv. Kans., Vol. II, p. 66.

H., *Myalina perattenuata* M. & H., *M. permiana* (Swallow) M. & H., *Nautilus eccentricus* M. & H., *Nuculana bellistriata* Stevens var. *attenuata* Meek, *Pleurophorus Calhouni* M. & H., *P. subcostatus* M. & W., *P. subcuneatus* M. & H., *Pseudomonotis Hawni* (M. & H.) sp., *P. Hawni* (M. & H.) sp. var. *ovata* M. & H., *Schizodus curtus* M. & W., *S. ovatus* M. & H., and *Yoldia subscitula* M. & H.

All of the species are Lamellibranchs with the exception of the *Nautilus* which is a Cephalopod. One species begins in the Lower Coal Measures; another is first reported from the Des Moines of Iowa and then from the Kansas Permian, not appearing in the interval; six appear in the Upper Coal Measures and the remaining six are known only in rocks of the age of Meek and Hayden's Kansas Permian, with one exception, which is reported from the Permo-Carboniferous of Utah and from rocks in New Mexico referred doubtfully to the Upper Coal Measures.

The abundant species and about the only ones found in the upper part of the formation are:

1. *Bakevellia parva* M. & H. — Permian of Kansas (in each instance meaning that division of Meek and Hayden), and from Arizona in rocks stated by Dr. White to probably belong in the Permian, while he found a closely related form in New Mexico "at the summit of the Carboniferous series" (U. S. Geog. Surv. W. 100 Merid., Vol. IV, p. 153). This species is closely related to *B. antiqua* Münster, which is common in the Permian of England, Germany, and Russia.

2. *Myalina permiana* (Swallow) M. & H. — Permian of Kansas and Texas. Reported by Hall & Whitfield from the Permo-Carboniferous of Utah; and by Dr. White from New Mexico in rocks which were referred doubtfully to the Upper Coal Measures.

3. *Pleurophorus subcuneatus* M. & H. — Permian of Kansas; Dr. Keyes reports: "There is but little doubt that the form from Des Moines [Lower Coal Measure of Iowa] is identical with that figured by Geinitz in 1866 as *Pleurophorus simplus* of Keyserling" (Proc. Acad. Nat. Sci., Phil., 1891, p. 250) There is no other record, however, of the occurrence of this species until Meek and Hayden's Permian is reached in Kansas, and Mr. Beede informs me that he has not seen it below the Permian there. This species is so nearly related to the *P. simplus* v. Keys. sp. of the Russian Permian that Geinitz regarded them as identical.

4. *Pseudomonotis Hawni* (M. & H.) sp. — Permian of Kansas. Heilprin

reported from the Upper Coal Measures of Pennsylvania "an obscure impression which may be that of this species, but very doubtful" (Second Geol. Surv. Pa., Ann. Rep., 1885, p. 455). Mr. Beede writes me, however, that it begins near the base of the Upper Coal Measures of Kansas, and he will shortly publish an article describing the Kansas species of this genus. This species was regarded by Swallow and Geinitz as identical with *P. speluncaria* Schloth. sp., which is a common Permian form in England and Germany.

5. *Myalina perattenuata* M. & H. also occurs near the top of the Marion and is reported from the Permian of Kansas and Texas, and the Upper Coal Measures of Missouri and Illinois.

The only Brachiopods found are specimens of *Derbya* from the lower part of the formation, which are doubtfully referred to the species *D. multistriata* M. & H. sp., which occurs in their Kansas Permo-Carboniferous. The disappearance of the Brachiopods was perhaps due in part to the diminished depth of the water, but in a much greater degree, undoubtedly, to the highly concentrated nature of the waters, as shown by the deposits of rock salt and gypsum. This change in the condition of the water affected the other forms of life unfavorably; but there remained, as we have seen, a meager Lamellibranch fauna which differed decidedly from the Lamellibranch fauna of the Coal Measures and is closely allied with the Permian Lamellibranch fauna of Europe.

The Wellington formation succeeds the Marion, varying in thickness from about 200 feet on the Smoky Hill River to 450 feet in Sumner county, near the southern line of the state,[1] in which, as far as known to the writer, no fossils have yet been found.

The Paleozoic of Kansas closes with the Cimarron group or the Red-beds, which in the southern part of the state are from 1150 to 1400 feet thick.[2] The absence of fossils has formerly made the correlation of this group rather indefinite. Professor Cragin has compared the stratigraphy of the Red-beds of the Kansas-Oklahoma basin with those of northern Texas and stated

[1] Univ. Geol. Surv. Kans., Vol. II, p. 67.

[2] *Ibid.*, p. 88.

that the gypsum beds of the Cave Creek formation, the top of which is about 250 feet below the summit of the Kansas Red-beds, apparently connect them "by a bond of stratigraphic continuity with the demonstrated Permian of Texas."[1]

Fossils have recently been found about 100 feet above the base of the Cimarron group in the northern part of Oklahoma. The most abundant specimens are species of a Phyllopod Crustacean which unfortunately were poorly preserved and, therefore, identified with some doubt by Professor T. Rupert Jones as *Estheria minuta* Alberti sp.[2] This species is characteristic of the Triassic in England, France, and Germany, apparently occurring most abundantly in the Keuper of the Upper Triassic.

Associated with the Crustacean fossils was the greater part of the skeleton of an Amphibian which has been identified by Professor Williston "as *Eryops megacephalus* Cope, a form described from the 'Permian' of Texas." Professor Williston, in discussing the importance of this discovery in reference to the age of the Red-beds, says: "This identification settles once for all the horizon whence it came as Permian, if the Texas beds be really of that age. There are several hundred feet of deposits in Kansas above this horizon that still possibly may be considered as Triassic, but there is no reason for so doing. *Estheria minuta* is a Triassic species, but, even if correctly determined, its value is slight in comparison with that of the vertebrate in the correlation of the beds. It must be remembered, however, that *Eryops* is by no means necessarily characteristic of the Permian."[3]

Professor Williston has written me as follows regarding Cope's correlation of the Texas deposits with the Permian: "In his first work upon the Texas beds Cope determined them as Triassic, and he seems never wholly to have overcome the idea

[1] Colorado College Studies, Vol. VI, p. 5; see also pp. 2, 3, 30, 48. The correlation of the Red-beds from this stratigraphic evidence was discussed by the writer in the Univ. Geol. Surv. Kans., Vol. II, pp. 89–92.

[2] Geol. Mag., Dec. IV, 1898, Vol. V, p. 292.

[3] Science, N. S., Vol. IX, Feb. 10, 1899, p. 221.

that they may not be of Triassic age, but in all his later papers upon the forms he refers to the beds as Permian. I suppose the reason for this collocation is the fact that the nearest related forms are found in the European Permian. Thus, *Euchirosaurus* and *Actinodon* are referred to the lower Permian in France (the Rothliegenden of Autun). I at first thought that the present form might be *Actinodon*, but the bones made out agree quite closely with the figures of *Eryops megacephalus* given by Cope."[1]

The above brief summary of the Permian rocks of Kansas shows that fossils occur in beds varying in thickness from 1000 to 1350 feet; while if all of the Red-beds are of the same general age, as is possible, the estimated total thickness of the Permian would then range from 2050 to 2650 feet. The majority of the species found in the lower 400 feet, the Permo-Carboniferous deposits, occur in the Upper Coal Measures (Missourian), and perhaps one half of the species in the succeeding 300 or 400 feet; but above that horizon none have been found which are even closely related to those in the Coal Measures. On the contrary, this higher fauna seems to be as nearly related to the Triassic as to the Carboniferous. This would seem to be sufficient proof that the greater part of Permian strata does not contain "precisely the same fauna as our Missourian or Upper Coal Measures," since only the lower 400 feet of deposits, ranging in thickness from 1350 to perhaps 2650 feet, contain a fauna composed largely of species which occur in the Upper Coal Measures. These lower beds are transitional, but this fact does not seem to the writer to furnish sufficient proof that the higher ones at least are not of Permian age.

CHARLES S. PROSSER.

UNION COLLEGE,
March 1899.

[1] Letter of Feb. 26, 1899.

THE NEBRASKA PERMIAN [1]

WHETHER or not true Permian rocks occur in Nebraska has been an open question for many years. Nevertheless, it has been customary for geologists mapping southeastern Nebraska to assign to it a narrow belt of territory extending from a point on the Nebraska-Kansas line sixty miles west of the Missouri River, north and east to Omaha. So far as the literature on the subject goes, there is absolutely no data that would warrant this construction. Probably these maps have been constructed upon the supposition that, since Permian rocks were known in Kansas, they might extend northward into Nebraska, and in case they did they would be found between the Carboniferous Coal Measures and the Dakota sandstone of the Cretaceous.

Professor Marcou [2] was the first geologist to suggest the occurrence of Permian rocks in Nebraska. Prior to that time the Paleozoic escarpments along the Missouri River had been considered Carboniferous by both Nicollet [3] and Owen.[4] In studying this region Professor Marcou made a very thorough examination, and it was his candid opinion that the rocks were

[1] In 1885, while a student in the University of Nebraska, the question of the occurrence of the Permian rocks in Nebraska came up in class and was thoroughly discussed, some maintaining the statements of Marcou, others those of Meek. The result was anything but satisfactory, and Dr. Hicks suggested to me that it would be a good plan to investigate the Paleozoic rocks of Nebraska and determine, if possible, whether there were any rocks that could be assigned to the Permian. This was carried out. The Missouri River, Platte River, Cass, Otoe, Richardson, Johnson, and Pawnee counties were visited, and Meek's conclusions that these rocks were Coal Measures confirmed. Still believing that the Permian rocks might occur in the southern portion of the state, work was resumed in Gage county. The data collected at that time are here presented in their original form, except that there are numerous references to Prosser's papers.

[2] Bull. Soc. Geol. France, 2 ser., Jan. 1864, Vol. XXI, pp. 134–137.

[3] NICOLLET's map.

[4] Report of the Geol. Surv. of Wis., Iowa, and Minn., and incidentally of a portion of Nebraska Territory, pp. 133–135.

Dyas (Permian). Later Professor Geinitz,[1] of Dresden, studied the fossils collected by Professor Marcou, and in an article confirmed Marcou's classification. The work of Marcou and Geinitz called forth some severe criticism from American geologists, which culminated in Professor Meek's masterly production in the Final Report of the U. S. Geological Survey of Nebraska, in which he proved conclusively that the Missouri River rocks extending from the mouth of the Platte River, southward along the Missouri River in Nebraska, were Coal Measures. The only recent publication bearing on the subject of the Missouri River rocks in Nebraska is an article published by Professor Prosser,[2] in which he strongly supports Meek's views. Without question these rocks must be considered Coal Measures.

Early investigators paid little or no attention to the Paleozoic exposures lying some distance west of the Missouri River. While making his reconnaissance for the final report on the geology of Nebraska, Dr. Hayden suggested that the true Permian rocks as found in Kansas might occur in some of the southern counties of Nebraska. However, his statements are very confusing and assure one that he had not arrived at any definite conclusion. While suggesting in a footnote[3] that the Kansas rocks might extend northward into Nebraska, on the same page, in discussing the Beatrice section, he says: "Beds 1, 2, and 3 of the above section are undoubtedly Permian or Permo-carboniferous, though they contain fossils common in both Permian and Carboniferous rocks. . . . . Bed 4 seems to form a sort of a transition bed between Permian and Carboniferous formations. The Permian rocks pass beneath water level at Beatrice westward," etc. The fossils on which the above statements in reference to the Beatrice section were made were *Syntrilasma* (*Enteletes*) *hemiplicata* and *Pinna peracuta*. Dr. Hayden visited many outcrops within the Permian area in Gage

[1] M. d. K. Leop. Carol. Acad. d. Naturl. Carbonformation und Dyas in Nebraska. Dresden, pp. vii + 91. 5 plates.

[2] Jour. Geol., Vol. V, No. 1, pp. 1–16, and No. 2, pp. 148–172.

[3] U. S. Geol. Surv. of Nebraska, final report, p. 28.

county while making his survey. In his report he mentions the bands of cherty limestone so characteristic of the Kansas beds and many other features that could only lead one to correlate these formations. Unfortunately, it has been found impossible to identify Dr. Hayden's sections along the Big Blue River. The reasons for this are apparent when it is known that he speaks of the bluffs at Blue Springs as being from ten to fifteen feet high, when in reality they vary from fifty to ninety above the river. Since Dr. Hayden's report nothing of importance was published pertaining to these rocks until 1886, when L. E. Hicks,[1] then Professor of Geology in the University of Nebraska, published two short papers. These articles were so general in character that it was impossible for any one to arrive at any definite conclusion regarding the area under discussion. In 1897 Prosser published two articles in which he discussed and reviewed the work of previous writers on the Paleozoic of Nebraska, and compared the Missouri River rocks with the Kansas beds. In the first of these articles[2] Prosser refers briefly to the exposures along the Big Blue River, and concludes by saying: "These rocks are undoubtedly of Permian age, and it is probable that the Neosho formation, and possibly a part of the Chase, occurs in Gage county."

Since the discovery of Permian rocks in Kansas by Swallow[3] there has been a considerable time devoted to their study by numerous geologists. The stratigraphical features are well known and the fauna has been carefully studied, although there is much to be accomplished in a more exhaustive study of the fossil life. Recently Prosser[4] has brought together all of the

[1] Transactions A. A. A. S., Buffalo meeting, 1886, and the American Naturalist, Oct. 1886, pp. 882, 883. The data embodied in these two articles were taken from my notes.

[2] JOUR. GEOL., Vol. V, p. 12.

[3] See Trans. Acad. Sci. St. Louis, Vol. I, pp. 111, 112.

[4] See Bull. Geol. Soc. Am., Vol. VI, pp. 29–54; JOUR. GEOL., Vol. III, 1895, pp. 682–705 and 764–800; University Geol. Surv. of Kansas, Vol. II, pp. 55–96. See also an article by PROFESSOR HAWORTH in the University Geol. Surv. of Kansas, Vol. I, pp. 185–194.

history bearing on these rocks, and added much valuable information to the literature by a careful examination of the many exposures. His classification must stand as a basis for correlating the Permian rocks of the central western United States.

The Nebraska Permian is the northern extension of Kansas beds, and agrees with them in all of the essential characters. The area is of a flatiron shape, with the broad end to the south resting upon the Kansas-Nebraska line. The northern limit is probably in the vicinity of Roca, Lancaster county. On the east the boundary has only been approximated, since the highlands separating the valley of the Nemaha from the valley of the Big Blue River, are so deeply buried with loess that there are few, if any, rock exposures. Typical Permian rocks were found near the eastern line of Gage county, and Coal Measures near Pawnee City, Pawnee county. From these data it is supposed that the eastern boundary of the Permian extends from Roca south and east into Johnson county, thence southward through the western end of Pawnee county into Kansas. The western boundary, from Roca to Beatrice, is also buried beneath a very thick bed of loess; but from Beatrice southward it was traced with considerable accuracy, since there were numerous outcrops of both Permian and Dakota sandstone. Only a short distance west of Beatrice the Dakota sandstone crosses the river and trends south and east along the southwestern border of the valley of the Big Blue River to a point known as "The Mounds," which is a high bluff capped by Dakota sandstone on the west bank of the river some two miles west of Holmesville. From this bluff, the highest in this section of the country, the boundary trends south and west, passing several miles west of Blue Springs, thence westward along the north side of Indian Creek to a point about two miles west of Odell, where it crosses the creek and turns eastward and follows the south side of the valley of Indian Creek nearly to the Big Blue River, where it bends southward and keeps a southern course to the Kansas line. As bounded, this area, comprising nearly five hundred square miles, is nearly confined to Gage county, and, with the exception of that portion in

Lancaster county, is drained by the Big Blue River and its tributaries. This river enters the central western border of the Permian field and flows eastward and southward through the western half into Kansas. All of its tributaries in the Permian rocks are small streams and of little importance.

The topography of this region is wholly unlike that of any other part of the state. There are highlands of almost level prairie, which change gradually into rolling prairie, and in some localities the rolling prairie shades into rough and broken country that is only fitted for pasture land. As the tributaries approach the river they usually flow through narrow, deep ravines or gulches, and in numerous places there are miniature canyons with precipitous walls of cherty limestone. The Big Blue River flows through a gradually narrowing valley. At Beatrice the bluffs are low and well rounded and the valley quite wide. In the vicinity of Holmesville, thc bluffs are very much higher and steeper, and near the Kansas line they are from fifty to one hundred and fifty feet high and in many places very precipitous. Where the exposures approach the perpendicular the walls are usually cherty limestone. The chert, which is almost black, occurs in regular bands of varying thicknesses. These exposures, when viewed from a distance, with their alternating layers of light and dark stone, partly vine-clad, remind one of the work of man rather than nature; and it does not require a vivid imagination for one to see ruin after ruin as the eye wanders down the river; here an old fortress, there an old church, and in the distance the rude outline of an old crumbling castle. This rugged scenery, mingled with the many groves and the winding river, makes this one of the most picturesque localities of the state. The elevation of this region above the sea varies from 1150 feet, at the state line, to about 1300 feet, on the divide between Roca and Beatrice. Judging from the deposits of drift along the river, the Permian has undergone glaciation. There are a few V-shaped troughs, varying in depth from two to five feet, and these are usually filled with granite and quartzite pebbles and sand. The Big Blue River was very near the southwestern limit of the great

ice sheet. North and east of Holmesville there are a few isolated patches of Dakota sandstone that have escaped glaciation.

In studying the Permian, work was commenced at Roca, but on account of the slight exposure and the scarcity of fossils, no detailed examination was made. A few specimens of *Enteletes hemiplicata* (Hall) were all the fossils seen, and the vertical range of this species is too great to allow it as evidence for or against the Permian. In the vicinity of Beatrice, only two slight exposures of yellowish shelly limestone were found. One of these was just below the dam, on the east bank of the river, and the other on the west side of the river in a ravine about a half mile southwest of the upper bridge. These rocks[1] were barren of fossils. By following the Union Pacific railroad down the river about a mile below town, a slight exposure of very poor limestone was found in a cut. From this point southward the limestone surface along the bluffs gradually rises above the railroad grade which follows the course of the valley. Three miles below Beatrice at the old cement mill, the following section was taken:

No. 4.	Soil and drift - - - - - - -	4 feet
No. 3.	Yellowish shelly limestone - - - -	4 feet
No. 2.	Cellular light gray limestone - - -	13 feet
No. 1.	Bluish hydraulic limestone - - - -	8 feet
	Total, - - - - - - - -	29 feet

No. 1 of this section was utilized during the seventies for manufacturing hydraulic cement. Nos. 1 and 2 contained the following fossils:

Productus semireticulatus Martin.
Ambocelia planoconvexa Shum.
Meekella striatioconstata Cox.
Seminula argentea Shep.
Bellerophon sp.

From the old cement mill down along the river on the east bank there are numerous exposures of the above section. At "The Mounds" the Permian is capped with about forty feet of brown Dakota sandstone, and the junction of the two formations

[1] DR. HAYDEN reports two species. See final report of the U. S. Geol. Surv. of Nebraska, p. 28.

is entirely obliterated with soil and débris. Numerous slight exposures of Permian rocks were found that were above the cement mill section and with them *Seminula argentēa* (Shep.) but no other fossil.

At Holmesville there were numerous exposures and many of them had been opened as quarries. To the north of the depot there is a quarry face over a quarter of a mile in length and averaging twenty feet in height. The limestones of this quarry are all thick bedded and one band has a peculiar habit of changing in color from a bluish to a cream color within a distance of twenty feet. South of the bridge there is a thin bed of oölite that thickens rapidly toward the south. It is very fossiliferous, but thins out before reaching the quarries north of the depot, where the following section was made :

No. 5. Soil, sand and drift - - - - - -	9 feet
No. 4. Yellowish to bluish limestone with geodes filled with quartz crystals, in some places cellular and containing fossils - - - - - -	10½ feet
No. 3. Bluish limestone - - - - - -	4 feet
No. 2. Cherty limestone - - - - - - -	6 feet
No. 1. Unexposed to the river - - - - -	14 feet
Total - - - - - - - -	43½ feet

The oölite has not been included in this section but belongs between Nos. 3 and 4, which are quarried for building purposes. The following fossils were taken from the oölite and No. 4.

Productus semireticulatus Martin.
Meekella striatiocostata Cox.
Aviculopecten occidentalis Shum.
Aviculopecten sp.
Aviculopecten sp.
Schizodus ovatus M. and H.
Schizodus wheeleri Swal.
Schizodus sp.
Yoldia subscitula M. and H.
Bakevellia parva M. and H.
Edmondia sp.
Edmondia sp.
Loxonema sp.

Pleurotomaria sp.
Murchisonia nebrascensis Gein.
Bellerophon montfortanus N. and P.
Naticopsis cf. *remex* White.

Southwest of Holmesville two and a half miles, on the west bank of the river, there is a long escarpment of very excellent limestone, that in early days was quarried and transported by wagons as far as Lincoln, to be used for building purposes. It occurs in good workable beds and breaks across the bedding as well as with it. When the stone is taken from the quarry it is easily cut with saw or plain, but upon exposure it becomes very much harder. When large dry blocks are struck with a hammer they have a metallic ring. It has been called magnesian limestone, and resembles very much the so-called magnesian limestones, that have been quarried from the Kansas Permian for many years.

SECTION OF QUARRY

No. 6.	Cream colored limestone	5/6 foot
No. 5.	" " "	2 ½ feet
No. 4.	" " "	3 ⅓ feet
No. 3.	" " "	3 feet
No. 2.	" " "	3 feet
No. 1.	Bluish and gray limestone	8 feet
	Total	20⅔ feet

The position of this section in reference to Holmesville is questionable. Levels were not run but there is some evidence that it occupies a place lower than the Holmesville bed. Possibly it may represent the Holmesville section in part; the differences in the strata being accounted for by a difference in sedimentation. Only a few fossils were found.

Aviculopecten occidentalis Shum.
Sedgwickia alteristriata? M. and H.
Myalina aviculoides M. and H.
Derbya robusta Hall.
Edmondia sp.
Pleurophorus sp.
Slight impressions of *Nautilus* or *Metacoceras* and a large pelecypod.

The next examination was made at Blue Springs. The bluffs opposite the town are from fifty to ninety feet above the river bed and extend down the stream for two or three miles. The most striking feature of these bluffs is the thick bed of cherty limestone that has not been seen to the northward, but which may yet be found at "The Mounds," or along some of the highlands away from the river. Below the cherty band along the bluffs, the slopes are in many places paved with large blocks of cherty limestone that have been loosened by frost. Above the cherty layer, there are several bands of workable limestone that have been quarried for building purposes. While the Blue Springs exposure is above the Holmesville, it is not definitely known what it rests upon. It is quite possible that there is a series of rocks intervening that have not been discovered.

BLUE SPRINGS SECTION

No. 10.	Soil	2 feet
No. 9.	Yellow shelly limestone	5 ½ feet
No. 8.	Compact yellowish limestone containing vertebrates and many invertebrates	7 ½ feet
No. 7.	Cherty limestone, fossiliferous	1 ½ feet
No. 6.	Yellowish soft limestone	1 ⅔ feet
No. 5.	Cherty limestone, fossils in chert	16 feet
No. 4.	Indurated and variegated marls	20 feet
No. 3.	Bluish limestone	10 feet
No. 2.	Unexposed	10 feet
No. 1.	Bluish limestone	3 feet
	Total	69⅔ feet

Nos. 7 and 8 contain a great many fossils, some of which are new to science. The following were collected:

Productus semireticulatus Shum.
Meekella striatiocostata Cox.
Orthis sp.
Seminula argentea Shep.
Aviculopecten occidentalis Shum.
Aviculopecten maccoyi M. and H.
Aviculopecten sp.
Orbiculoidea sp.

Orbiculoidea sp.
Bellerophon sp.
Myalina permiana? Swal.
Rhombopora lepidodendroides? Meek.
Myalina aviculoides M. and H.
Dentalium sp.
Derbya crassa M. and H.
Derbya robusta Hall.
Strapharollus subrugosus M. and H.
Archeocideris sp.
Fenestella sp.
Polypora sp.
Fistulipora sp.
? ? Ceromya sp. probably a new genus of pelecypods.
Vertebrates:
Styptobasis knightiana Cope.
Diplodus sp. nov.

Professor Cope[1] in describing Styptobasis as a new genus remarked: "This was a large shark of carnivorous habits, and its presence indicates the existence of a marine fauna whose remains have not been discovered." Associated with No. 8 was a huge Pinna nearly three feet long.

Quarries and exposures were also examined in the vicinity of Wymore, but no additional data were secured, since the sections were the same as at Blue Springs.

At Odell several slight exposures were found along the bluffs, and one in a small gulch west of the town. From the last one mentioned a single specimen of *Chænomya minnehaha* (Swal.) was taken. On account of the exposures being slight, and no chance to study more than a few feet of limestone, the Odell region was not worked over. From a few measurements of rock in place the dip was found to be slightly to the southwest.

The exposures along the river south from Wymore, are very numerous and in many places form continuous bluffs, but none of these were critically examined until the Kansas-Nebraska line was reached. Here there were the finest exposures seen along

[1] See COPE'S description, Proceedings of the U. S. Nat. Museum, Vol. XIV, pp. 447, 448.

the river, and they were also quite accessible for study. The cherty band as seen at Blue Springs can be seen on every bluff, and the limestones above resemble the stone quarried at the Blue Springs quarries. But above all of these bands, there are several that have not been seen to the north. The following section was made at the state line.

No. 7.	Yellowish oölitic limestone - - - -	8½ feet
No. 6.	Light colored limestone, shelly - - -	4 feet
No. 5.	Yellowish limestone - - - - -	8 feet
No. 4.	Light colored limestone with some chert -	13 feet
No. 3.	Very cherty limestone - - - - -	15 feet
No. 2.	Indurated marls, variegated - - -	15 feet
No. 1.	Unexposed to the river - - - - -	20 feet
	Total - - - - - - - -	73½ feet

No fossils were found below the cherty bands. Nos. 5, 6, and 7 contained a great many fossils, No. 7 being especially rich in species as well as in numbers. The following is a partial list. Many of the fossils were so frail that by the time they had been packed, shipped, and unpacked no one could identify them,

Nautilus eccentricus M. and H.
Metacoceras dubium Hyatt.
Metacoceras sp.
Myalina aviculoides M. and H.
Myalina perattenuata M. and H.
Myalina permiana Swal.
Myalina sp.
Seminula argentea Shep.
Pseudomonotis hawni M. and H.
Pseudomonotis hawni ovata M. and H.
Pseudomonotis sp.
Meekella striaticostata Cox.
Derbya crassa M. and H.
Derbya robusta Hall.
Aviculopecten occidentalis Schum.
Aviculopecten sp.
Bakevellia parva M. and H.
Pinna sp.
Yoldia subscitula M. and H.
Schizodus sp.

Schizodus sp.
Solenomya sp.
Solenomya sp.
Fenestella sp.
Pleurophorus sp.
Edmondia sp.
Scaldia sp. nov.
Allorisma subcuneata M. and H.
Allorisma cf. *elegans* King.
Chaenomya laevenworthensis M. and H.
Bellerophon marcouanus Gein.
Bellerophon sp.
Avicula cf. *lanceolata.*
Orthoceras sp.

At Oketo, Kan., two miles south of the state line, there are large quarries worked in the bands above the cherty limestone. The exposures along the bluffs at Oketo were the same as seen at the state line, except there were a few new bands above the oölitic limestone. The cherty limestone band that has been traced from Blue Springs to the state line and on to Oketo is, beyond question, the same band that outcrops to the north of Marysville, Kan., and that it is the Florence[1] flint of Prosser's Chase formation. If this correlation is correct, the cherty limestone that is only partly exposed at Holmesville will equal the Strong flint of Prosser's Kansas section, in which case the Chase formation would extend as far north as Beatrice, and the Neosho from Beatrice to Roca. There are some stratigraphical differences noted while comparing the formations of the two states, but this will undoubtedly disappear with more detailed study. The most marked is the occurrence of oölites in Nebraska that have not been reported from Kansas. Prosser calls the variegated band underlying the Florence flint a shale, while the same band in Nebraska is an indurated marl. At all exposures attempts were made to take the dip, but as a rule the readings were anything but satisfactory. At Holmesville and Blue Springs there were places, which appeared to be caused by warping, where

[1] See PROSSER'S conclusion as to the Marshall county, Kansas rocks, Vol. V, JOUR. GEOL., p. 12.

the strata dipped slightly to the east, but in the same quarries one could find slight dips in almost any direction. By comparing the height of the base of the Florence flint with the railroad grade at Blue Springs and Oketo, it was found that these rocks had a southern dip of five feet to the mile. This information, coupled with the readings taken at Odell, makes it very certain that these rocks dip to the southwest.

In comparing the fossil life of the two states there are greater differences than one might expect, especially when the Upper Permian rocks are not known to Nebraska. So far there are many more lingering Coal Measure species reported from Kansas than Nebraska. As soon as the questionable species of both states have been classified, the greatest differences in the fauna will disappear. There is another interesting point that is not out of place here. There are a few species of invertebrates reported from the Texas Permian that are common to the Permian of Kansas and Nebraska, and beyond question, when the Texas species of gasteropods and pelecypods have been reported in full, there will be many more species common. It seems very probable that the Permian of Kansas and Texas was at one time connected, and that it also stretched westward and northward to, and possibly beyond, the Rocky Mountains. Many of the early geologists connected with the geological surveys of the territories considered that the uppermost rocks of the Paleozoic in the mountain region was Permian, and so recorded it; but owing to the lack of paleontological evidence, but few, if any, have ever considered this classification correct. Only recently fossil horizons of great importance have been discovered in what will in the future be known as the mountain Permian. These fossils are in part the same as those found in the Permian of Kansas and Nebraska, but with them are numerous forms new to science which are decidedly Mesozoic in character. When the mountain formations have been thoroughly investigated, the Permian area of the United States will be materially increased.

Some may question whether there are any true Permian rocks[1]

[1] See PROSSER's discussion of this subject in Vol. III, JOUR. GEOL., pp. 789–796.

in America. A discussion of this subject cannot be taken up here, but the following notes are worthy of consideration. Of the forty-four genera of invertebrates known in the Kansas and Nebraska rocks, over three fourths of them belong to the Permian of the Orient. The remainder are nearly all American genera and are chiefly pelecypods. In referring to the English Permian it will be seen that there are reported thirty species of brachiopods and thirty-seven species of pelecypods, while in America, with a fauna only partially known, there are fifteen brachiopods and between forty and fifty species of pelecypods. Besides this, there is the disappearance of the Spirifers, the most of the Producti, and the most of the typical Coal Measure species.

Some have objected to the use of the term Permian to designate an American terrane. There seems to be no good reason for this. In this country, as in Europe and India, there is a series of rocks above the Coal Measures that cannot be consistently classified with them. While they are linked with the Paleozoic with unmistakable affinities, they are also bound to the Mesozoic by indubitable bonds. Since the term Permian has been in use many years to represent this formation, in this, as well as foreign countries, it seems ill advised at this time to introduce a new term to designate the American formations. We might as consistently cast off other period names that have had their origin in a foreign country. Since the Permian is a typical transition series, it seems advisable to speak of it as a geological period of the Paleozoic, and no longer consider it an epoch of the Carboniferous.

In order to show the close relationship of the American and foreign Permian, a table has been arranged which will give all of the genera known to the Kansas and Nebraska Permian, and also show their distribution in the foreign Permian. The resemblance is even greater than appears in the table, since it has been impossible to secure accurate data relating to many of the foreign genera.

A TABLE GIVING THE KANSAS AND NEBRASKA (AND IN PART THE TEXAS) PERMIAN INVERTEBRATE GENERA AND THEIR DISTRIBUTION IN THE FOREIGN PERMIAN

	England	Russia	Germany	India	Kansas	Nebraska	Texas
Anthozoa.							
Zaphrentis	..	..	..	..	+	..	..
Chaetetes	+	+	..	..	+	..	..
Echinoidea.							
Archaeocidaris	+	+	..	..	+	+	..
Annelida.							
Spirorbis	..	..	..	..	+	..	+
Bryozoa.							
Fenestella	+	+	+	+	..	+	..
Polypora	..	+	+	+	+	+	..
Septopora	..	..	..	+?	+	..	..
Rhombopora	..	..	..	+	+	+	..
Fistulipora	..	..	..	+	..	+	..
Brachiopoda.							
Orbiculoidea	+	+	+	..	+	+	..
Productus	+	+	+	+	+	+	..
Chonetes	+	+	+	+	+	..	..
Orthis	..	+	+	+	..	+	..
Derbya	+	..	+	+	+	+	..
Enteletes	..	..	+	+	+	..	..
Ambocoelia	..	..	..	..	+	+	..
Seminula	+	+	+	+	+	+	..
Pelecypoda.							
Aviculopecten	+	+	+	+	+	+	+
Avicula	+	..	..	+	..	+?	..
Pseudomonotis	+	+	+	+	+	+	..
Pinna	+?	+	+?	..	+	+	..
Macrodon	+?	..	..	+	+	..	..
Myalina	..	+	..	..	+	+	+
Nuculana	..	+	..	+	+	..	..
Nucula	+	+	..	+	+	..	..
Yoldia	..	..	..	..	+	+	+
Bakevellia	+	+	+	+	+	+	+
Schizodus	+	+	+	+	+	+	..
Pleurophorus	+	+	+	+	+	+	+
Scaldia	..	..	..	..	..	+	..
Edmondia	+	+	..	+	+	+	..
Solenomya	+	+	+	..	..	+	..
Ceromya ?	..	..	..	..	..	+	..
Sedgwickia	..	..	..	..	+	+	+
Chaenomya	..	..	..	..	+	+	..
Allorisma	+	+	+	+	+	+	+
Glauconema	..	..	..	..	+	..	..
Schaphopoda.							
Dentalium	+	..	+	..	+	+	..
Gasteropoda.							
Bellerophon	..	..	+	+	+	+	+
Loxonema ?	+	+	+	..	+	..	..

A LIST OF THE KANSAS AND NEBRASKA PERMIAN FOSSILS [1]

	England	Russia	Germany	India	Kansas	Nebraska	Texas
Gasteropoda.							
Macrocheilus	+	..	+	+	+	..	..
Orthonema ?	..	..	..	..	+	..	..
Aclisina	..	..	..	..	+	..	..
Strapharollus	+	..	+	+	+	+	+
Naticopsis	..	..	..	+	+	+	+
Pleurotomaria	+	+	+	+	+	+	..
Murchisonia	..	+	+	+	+	+	+
Cephalopoda.							
Orthoceras	..	..	..	+	..	+	+
Nautilus	+	..	+	+	+	+	+
Metacoceras	..	..	..	..	+	+	..
Phacoceras	..	..	..	..	+	..	..
Crustacea.							
Phillipsia	+?	..	..	..	+	..	..
Pisces.							
Styptobasis	..	..	..	..	..	+	..
Diplodus	..	..	..	..	..	+	..

	Nebraska	Kansas	Texas
Fistulipora sp	+	..	..
Chaetetes cf. *carbonaria* Worth	..	+	..
Zaphrentis sp	..	+	..
Archaeocideris sp	+	..	..
Archaeocideris sp	..	+	..
Spirorbis cf. *permianus* King	..	+	..
Spirorbis? orbiculostoma Swal	..	+	..
Spirorbis sp	..	+	..
Fenestella shumardi Prout	..	+	..
Fenestella sp	+	..	..
Polypora submarginata Meek	..	+	..
Polypora sp	+	..	..
Rhombopora lepidendroides Meek	+?	+	..
Rhombopora sp	+	..	..
Septopora biserialis Swal	..	+	..
Orbiculoidea sp	..	+	..
Orbiculoidea sp	+	..	..
Orbiculoidea sp	+	..	..
Productus semireticulatus Martin	+	+	..
Productus semireticulatus calhouni Swal	..	+	..
Productus nebrascensis Owen	..	+	..
Productus costatus Sowb	..	+	..
Chonetes granulifera Owen	..	+	..
Orthis sp	+	..	..
Derbya crassa M. & H.	+	+	..
Derbya multistriata M. & H.	..	+	..
Derbya robusta Hall	+	..	..
Meekella striaticostata Cox	+	+	+
Meekella shumardiana Swal	..	+	..

[1] The fossils reported from Kansas are those that have recently been reported by Professor Prosser. The Texas list has been reported by Professor Cummings, and the Nebraska from my collections.

A LIST OF THE KANSAS AND NEBRASKA PERMIAN FOSSILS—*continued*

	Nebraska	Kansas	Texas
Meekella sp	+	..	..
Enteletes hemiplicata Hall	+	+	..
Ambocoelia planoconvexa Shum	+	+	..
Seminula argentia Shep	+	+	..
Aviculopecten occidentallis Shum	+	+	+
Aviculopecten carboniferous Stevens	..	+	..
Aviculopecten maccoyi M. & H.	+	+	..
Aviculopecten sp	+	..	..
?*Avicula* cf. *lanceolata*[1]	+	..	..
Pseudomonotis hawni M. & H.	+	+	..
Pseudomonotis hawni ovata M. & H	+	+	..
Pseudomonotis cf. *variabilis* Swal.	..	+	..
Pseudomonotis sp	+	..	..
Pinna peracuta Shum	+	+	..
Pinna sp. nov	+	..	..
Pinna sp. nov	+	..	..
Pinna sp. nov	+	..	..
Myalina recurvirostris M. & W	..	+	..
Myalina perattenuata M. & H.	+	+	+
Myalina kansasensis Shum	..	+	..
Myalina permiana Swal	+	+	—
Myalina aviculoides M. & H.	+	..	+
Myalina swallovi McChes.	..	+	..
Myalina sp	+	..	..
Nuculana bellistriata attenuata Meek	..	+	..
Nucula cf. *beyrichi* Schauroth	..	+	..
Yoldia subscitula M. & H	+	+	+
Bakevellia parva M. & H.	+	+	..
Schizodus curtus M. & H.	..	+	..
Schizodus ovatus M. & H	+	+	..
Schizodus wheeleri Swal	+	..	..
Schizodus cf. *curtiformis* Walcott	..	+	..
Schizodus sp	+	..	..
Schizodus sp	+	.	..
Pleurophorus subcostatus M. & W	..	+	..
Pleurophorus cf. *oblongus* Meek	..	+	..
Pleurophorus subcuneatus M. & H.	..	+	..
Pleurophorus sp	+	..	..
Pleurophorus sp	..	+	..
Scaldia sp. nov	+	..	..
Edmondia calhouni M. & H.?[2]	..	+	..
Edmondia cf. *nebrascensis* Gein	..	+	..
Edmondia sp	+	..	..
Edmondia sp	..	+	..
Solenomya sp	+	..	..
Solenomya sp	+	..	..
?? *Ceromya* sp. nov	+	..	..
Sedgwickia altirostrata M. & H	+?	+	..
Chaenomya minnehaha Swal	+	+	..
Chaenomya laevenworthensis M. & H	+	..	..

[1] Atlas of Fossil Conchology, Brown, Plate LXIX, Fig. 3.

[2] This has recently been referred to Pleurophorus. See Bull. U. S. Geol. Surv., No. 153, by STUART WELLER, p. 242.

A LIST OF THE KANSAS AND NEBRASKA PERMIAN FOSSILS—*continued*

	Nebraska	Kansas	Texas
Allorisma subcuneatum M. & H.	+	+	+
Allorisma cf. *elegans* King	+	..	..
? *Glauconome* sp.[1]	..	+	..
Dentalium meekanum Gein (?).	..	+	..
Dentalium sp.	+	..	..
Bellerophon montfortanus N. & P.	+	+	+
Bellerophon, cf. *sublaevis* Hall.	..	+	..
Bellerophon marcouanus Gein	+	..	..
Bellerophon sp.	+	..	..
Bellerophon sp.	..	+	..
Loxonema ? sp.	+	+	..
Macrocheilus angulifera White[2]	..	+	..
Orthonema ? sp.	..	+	..
Aclisina robusta Stevens.	..	+	..
Aclisina swallovana Gein	..	+	..
Strapharollus subrugosus M. & W.	+	+	..
Strapharollus subquadratus M. & W.	..	+	+
Strapharollus pernodosus M. & W.	..	+	..
Naticopsis, cf. *remex* White	+	..	+
Pleurotomaria sp.	+	..	..
Murchisonia, cf. *nebrascensis* Gein	+	..	..
Murchisonia sp. nov.	+	..	..
Orthoceras sp.	+	..	..
Nautilus eccentricus M. & H.	+	+	..
Metacoceras dubium Hyatt.	+	+	..
Metacoceras sp.	+	..	..
Metacoceras sp.	—	..	..
Phacoceras dumbli Hyatt	..	+	..
Phillipsia sangamonsis M. & W.	..	+	..
Phillipsia sp.	..	+	..
Styptobasis knightiana Cope	+	..	..
Diplodus sp. nov.	+	..	..

W. C. KNIGHT.

[1] Referred by STUART WELLER to Pinnatopora. See Bull. U. S. Geol. Surv., No. 153, p. 288.

[2] Conditionally referred to *Soleniscus angulifera*. See Bull. U. S. Geol. Surv., No. 153, p. 339.

THE DIAMOND FIELD OF THE GREAT LAKES

THE diamonds which have from time to time been discovered in the region of the Great Lakes of North America, now number seventeen, not including those of microscopic size. With the augmentation of the number of stones the problems arising out of their distribution in the glacial drift, and particularly those relating to the source or sources from which they have been derived, assume increasing interest.

HISTORICAL INTRODUCTION

The first mention of diamonds from this region in any scientific work appears in the *Mineral Resources of the United States for the year 1883–4*,[1] in which Kunz refers to the sensation caused by the reported diamond discovery near Waukesha, Wisconsin, in 1883. The "booming" of the property for diamond mines and the alleged discovery subsequently of two diamonds which Kunz found to have the aspect of African stones, very naturally led this eminent authority to discredit the discovery at this place of the larger stone as well, and to consider the entire affair as a so-called "plant" to influence speculation.

In the summers of 1887, 1888, and 1889, Mr. G. H. Nichols, of Minneapolis, assisted by Messrs. W. W. Newell and C. A. Hawn, of Rock Elm, Wis., prospected for gold in the bed of Plum Creek, Rock Elm township, Pierce county, Wisconsin. In the course of their work they found ten or more diamonds, varying in weight from ½ carat to 2 carats, besides a number of stones of microscopic dimensions.[2] The stones were found

[1] G. F. KUNZ: Mineral Resources of the United States, U. S. Geol. Surv. 1883–4 (1885), p. 732; see also Gems and Precious Stones of North America, New York, 1890, p. 35.

[2] G. F. KUNZ: Diamonds in Wisconsin, Eng. and Min. Journ., Vol. L, 1890, p. 686; see also a paper by the same author in Bull. Geol. Soc. Am., Vol. II, 1891, p. 638.

in the well-worn gravel of the bed of the creek, associated with garnets, gold, and platinum. Some were colorless but others were bluish or slightly yellowish. Three of the stones, which were sent to Mr. Kunz for examination, weighed respectively $\frac{25}{32}$, $\frac{7}{16}$, and $\frac{3}{32}$ of a carat.

In November 1893, a white diamond of $3\frac{14}{16}$ carats, weight was brought to the writer in a collection of quartz pebbles, by Charles Devine, a farmer of Oregon, Dane county, Wisconsin. The stones had been found in October of the same year by a small son while playing in a clay bank on the farm of Judson Devine, in the town of Oregon, which is about twelve miles south of Madison.[1]

The writer's interest having been aroused in the occurrence of these stones, he began to investigate the Waukesha sensation and after some correspondence learned that a yellow diamond of over 15 carats weight was in the possession of Colonel S. B. Boynton, a jeweler of Chicago. From Mr. Boynton was learned the history of this stone, which was undoubtedly found as reported, at Eagle, near Waukesha, Wisconsin. The stone was brought to light in 1876 while digging a well on the farm then owned by Thomas Deveraux. The diamond was noted as something peculiar, and was given to Mrs. Clarissa Wood, who, with her husband, was a tenant on the property. Seven years later, in November 1883, while still ignorant of the real nature of the stone, she sold it to Mr. Boynton, at that time conducting a jewelry business in Milwaukee, for the sum of one dollar. Colonel Boynton submitted the stone to competent examination and learned that it was a diamond. Upon hearing of this Mrs. Wood offered to repurchase the stone for $1.10, and upon his refusal to accept this offer, brought suit against him to recover the full value of the stone. After extensive litigation the case was brought to the supreme court of the state, from which a decision was handed down in favor of the defendant, on the

[1] Wm. H. Hobbs: On a recent Diamond Find in Wisconsin, and On the Próbable Source of this and other Wisconsin Diamonds, Am. Geol., Vol. XIV, 1894, pp. 31-35; see also, Diamanten von Wisconsin, Neues Jahrb. f. Mineral., 1896, II, p. 249.

ground of his ignorance of the nature of the stone at the time of purchasing it.

The writer called upon Colonel Boynton at Chicago, and was allowed to examine the stone. Both it and the Oregon diamond were subsequently purchased by Tiffany & Co., of New York, and are still uncut in the Tiffany collection.[1]

Through Mr. Boynton the writer learned that a large diamond had been found in 1884 (this date should be 1886), by a farmer named Endlich, at Kohlsville, near West Bend, Washington county, Wisconsin. The stone had been brought to Mr. Boynton's shop for examination, and he had remembered it as a wine-yellow diamond, weighing 21¼ carats. After considerable correspondence this diamond was located by the writer in the possession of Mrs. Louis Endlich, of Kewaskum, Wis, the widow of the man who had discovered the stone in the neighboring town of Kohlsville. On visiting Kewaskum the writer was allowed to examine the stone, which proved to be in all respects as described by Colonel Boynton, and there is no doubt that the weight (21¼ carats) reported by him is approximately correct, since this stone is considerably larger than the one from Eagle. Mrs. Endlich stated that her diamond was found by her husband in the spring of 1886 while plowing a field on his farm in the town of Kohlsville.[2] This stone is still in her possession.

In 1894 Mr. Kunz reported the finding by Mr. Frank B. Blackmond of a diamond weighing almost 11 carats, at Dowagiac, Cass county, Michigan. This locality is to the southeast of Lake Michigan, on the Michigan Central railway, between Niles and Kalamazoo. The stone was found in the glacial drift and some search was subsequently made in the vicinity for other stones, but with negative results.[3]

[1] WM. H. HOBBS: *loc. cit.*, p. 32.

[2] WM. H. HOBBS: N. J. B., 1896, II, p. 33; also Bull. Univ. Wis., Sci. Ser., Vol. I, 1895, pp. 152–154; see also, G. F. KUNZ: Eighteenth Annual Report U. S. Geol. Surv. Pt. IV, 1895, p. 596.

[3] G. F. KUNZ: Sixteenth Annual Report U. S. Geol. Surv., 1895, Pt. IV, p. 596.

In March, 1896, a stone was brought to the office of the Wisconsin state chemist, at Milwaukee, which, on examination, proved to be a white diamond of nearly 6½ carats weight. It was found by Conrad Schaefer, a German farmer at Saukville, Ozaukee county, Wisconsin. In a letter to the writer, Mr. Schaefer says of this stone (translation):

> This diamond is from a little collection of gems, stones, and fossils, also Indian implements, all collected on my land. My land adjoins the Milwaukee River, and is a drift range running northeast and southwest. I had the stone about fifteen or sixteen years in my possession.

This diamond was purchased by Messrs. Bunde & Upmeyer, the well-known Milwaukee jewelers.[1]

In 1893 Messrs. Bunde & Upmeyer purchased from Mrs. G. Pufahl a white diamond of about 2 carats weight, said to have been found at Burlington, Racine county, Wisconsin. Little was learned at the time of the circumstances attending the finding of this stone, and the writer's subsequent attempts to get into communication with Mrs. Pufahl, though kindly assisted by Messrs. Bunde & Upmeyer, have not been successful. Like most of the others, this diamond was probably found in the glacial drift.[2]

The latest diamond to come from the region under consideration was found so recently that nothing is in print concerning it, except in the newspapers. It is a diamond of purest water, weighing 6 carats, and was found in 1897 by two small daughters of J. R. Taylor, at the town of Milford, Clermont county, Ohio. It is now owned by Herman Keck, of Cincinnati, and has recently been cut into the form of a brilliant. Before cutting a cast was taken of it and the stone is now being studied by Professor Thomas N. Norton, of the University of Cincinnati.

It is seen from the foregoing that no less than seventeen well-identified diamonds, varying in weight from ½ carat to over 21 carats, have been discovered in the region of the Great Lakes of North America. That a considerable number of others have been found which have not been reported because they have

[1] G. F. KUNZ: Eighteenth Annual Report U. S. Geol. Surv., 1897, Pt. V, p. 1183.

[2] G. F. KUNZ: *Ibid.*

escaped identification, hardly admits of reasonable doubt, when it is borne in mind that three of the stones found (including the two of largest size) remained in the hands of the farming population without their nature being discovered, for periods of eight and one half, seven, and over fifteen years, respectively. If it were possible to visit all the homes in the lake region, I have no doubt that many diamonds would be discovered in the little collections of pebbles and local "curios" which accumulate on the clock shelves of country farmhouses.

Since 1894, when the writer published a note on the Eagle, Oregon, and Kohlsville diamonds, and ventured to predict that other diamonds would occasionally be found in the glacial drift, they have been coming to light in this region, at the rate of about one each year, though not apparently as the result of search in any case.

PHYSICAL CHARACTERISTICS OF THE LAKE DIAMONDS

It will be profitable to consider the physical peculiarities of the several diamonds which have been found in the lake region, and to compare them with one another in order to determine whether points of resemblance or of difference are the more remarkable. They may be considered in respect to size, form, surface, and color. The observations of specific gravity and of index of refraction, which would be of great interest, have not as yet been carried out upon them.

Size.—The size of the lake diamonds is best indicated by their weights, which range from $21\frac{1}{4}$ carats (Kohlsville) to the microscopic diamonds of Plum Creek. In descending order the weights of the stones which have been examined are respectively $21\frac{1}{4}$, $15\frac{12}{32}$, $10\frac{7}{8}$, $6\frac{13}{32}$, 6, $3\frac{14}{16}$, $2\frac{1}{16}$, 2, $\frac{25}{32}$, $\frac{7}{16}$, and $\frac{3}{32}$ carats. While the average weight of these is over 6 carats, it cannot be considered an average for the region, since only the larger stones are likely to be discovered until a systematic search is undertaken in the region. At Plum Creek, where panning of the gravels was undertaken, the diamonds found were mostly small, the largest being of 2 carats weight.

Crystal form.—The crystal form of the lake diamonds furnishes the most important method of comparing them. The prevailing forms are the rhombic dodecahedron, the rhombic dodecahedron with vicinal faces of a hexoctahedron, and a hexoctahedron. The exceptions to the rule are found in the Saukville stone, a trisoctahedron; the Burlington stone, a tetrahedron; and the Milford stone, which from the newspaper accounts would seem to be an octahedron. Twinning was observed in one of the Plum Creek diamonds (in a hexoctahedron) and in the Burlington stone (in a tetrahedron).

The crystals possessing dodecahedral and hexoctahedral habits show, therefore, close affinities in their crystal forms, the Eagle and Kohlsville stones, which are crystallographically almost identical, being essentially intermediate between the Oregon dodecahedron and the Plum Creek and Dowagiac hexoctahedrons. On all the crystals the faces are rounded, and unequal development has produced distortion. The Eagle diamond approaches nearer to the ideal form than any of the others which I have examined.

Surface.—Surface markings are common to most of the stones. These are generally pittings, irregular in some cases, but generally circular or triangular. On the Eagle stone there are triangular elevations.

Color.—The color of the diamonds in this region varies from "white" to white tinged with green, and to pale yellow. The stones of Milford and Saukville are "white." White stones with faint grayish-green tinge (probably external) were found at Oregon and Burlington, and one from Plum Creek; while the Eagle and Kohlsville stones and some of those from Plum Creek are "Cape-white" (pale yellow). The several stones exhibit also varying degrees of transparency, the Milford stone particularly being of a remarkably pure water.

For purposes of comparison the most important facts regarding the larger diamonds have been brought together in the table on the opposite page.

Locality Where	Present Owner	Where Described
Eagle, Waukesha Co., farm owned (1876) by Devereaux	iffany & Co., New York	Am. Geol., 14 (1894), 31 N. J. B., 1896, II, 249
Plum Creek, Rock El ship, Pierce Co., W stones, ranging in ½ to 2 carats, and a of microscopic size	Do. Do. Do.	Eng. & Min. Jour., 50 (1890), 686 Bull. G. S. A., 2 (1891), 638 Min. Res. U. S., 1892 (1893), 759
Oregon, Dane Co., farm of Judson De miles southwest of v	Do.	Am. Geol., 14 (1894), 31 N. J. B., 1896, II, 249 Min. Res. U. S., 1893 (1894), 682
Kohlsville, Washing Wis., on the farm Endlich	Widow of L. Endlich, Kewaskum, Washington Co., Wis.	Am. Geol., 14 (1894), 31 Bull. Univ. Wis. (Sci.), 1 (1895), 152 18th Ann. Rept. U. S. G. S., Pt. V, 1183
Dowagiac, Cass Co., M		16th Ann. Rept. U. S. G. S., Pt. IV (1895), 596
Saukville, Ozaukee C on farm of Conrad S	Bunde & Upmeyer, Milwaukee	18th Ann. Rept. U. S. G. S. (1897), Pt. V, 1183
Burlington, Racine Co	Do.	Do.
Milford, Clermont Co.	Ierman Keck, Cincinnati	Not yet described

DATA REGARDING DIAMONDS FOUND IN THE REGION OF THE GREAT LAKES

Locality Where Found	Weight in Carats	Size	Crystal Form	Surface Markings	Color	Date of Finding	Date of Determination, and by Whom	Finder	Material in which Stone was Found	Present Owner	Where Described
Eagle, Waukesha Co., Wis., on farm owned (1876) by Thomas Devereaux	15 12/32		Rhombic dodecahedron, with vicinal faces of hexoctahedron. Only slightly distorted	Faces show circular markings; also triangular elevations	"Cape White" (pale yellow)	1876	1883; 1893 G. F. Kunz, and the writer	Laborer employed by Mrs. Clarissa Wood, of Eagle	Gravel and clay of kettle moraine cemented by ferric oxide into hard yellow matrix	Tiffany & Co., New York	Am. Geol., 14 (1894), 31 N. J. B., 1896, II, 249
Plum Creek, Rock Elm Township, Pierce Co., Wis. Ten stones, ranging in size from ⅙ to 2 carats, and a number of microscopic size	(a) 3/32 (b) 1/16 (c) 3/32		(a) Hexoctahedron (b) Elongated hexoctahedron (c) Elliptical hexoctahedral twin	(a) An L-shaped depression on the side, with rounded faces, including sand grains (b) Surface covered with small crystalline markings (c) Surface dull	(a) White, with slight grayish-green tinge (b) Slightly yellowish (c) White tinged yellow	1887 1888 1889	1891 G. F. Kunz	G. H. Nichols, Minneapolis W. W. Newell and C. A. Hawn, Rock Elm, Wis.	Sand of stream bed containing quartz, magnetite, titanic iron, almandite, spessartite or hessonite, monazite, gold, and platinum	Do. Do. Do.	Eng. & Min. Jour., 50 (1890), 686 Bull. G. S. A., 2 (1891), 638 Min. Res. U. S., 1892 (1893), 759
Oregon, Dane Co., Wis., on farm of Judson Devine, [illegible] miles southwest of village	[illegible]		Rhombic dodecahedron distorted	Deeply pitted with circular and elongated reniform markings	White, with slight gray-green tinge (probably superficial)	October 1893	November 1893 The writer, and later G. F. Kunz	Son of Chas. Devine, Oregon	With pebbles of quartz in clay, kettle moraine	Do.	Am. Geol., 14 (1894), 31 N. J. B., 1896, II, 249 Min. Res. U. S., 1893 (1894), 682
Kohlsville, Washington Co., Wis., on the farm of Louis Endlich	21¼	20 mm × 13 mm × 10 mm	Elongated rhombic dodecahedron, with vicinal planes of hexoctahedron	All the faces have small irregular shaped pittings	Pale yellow	Spring 1880	September 1894 The writer	Louis Endlich, of Kohlsville	Hard yellow ferruginous matrix in kettle moraine	Widow of L. Endlich, Kewaskum, Washington Co., Wis.	Am. Geol., 14 (1894), 31 Bull. Univ. Wis. (Sci.), 1 (1895), 152 18th Ann. Rept. U. S. G. S., Pt. V, 1183
Dowagiac, Cass Co., Mich.	10⅞	13 mm × 9 mm × 11 mm	Hexoctahedron			1894 (?)	1894 G. F. Kunz	Frank B. Richmond	In kettle moraine		16th Ann. Rept. U. S. G. S., Pt. IV (1895), 596
Saukville, Ozaukee Co., Wis., on farm of Conrad Schaefer	[illegible]½		Flattened distorted trisoctahedron	Irregular, uneven surface, with deep octahedral impression on one side	White, with two yellow stains	1880	March 1896 Dr. Mitchell, State Chemist, and later G. F. Kunz	Conrad Schaefer, Saukville	In kettle moraine	Bunde & Upmeyer, Milwaukee	18th Ann. Rept. U. S. G. S. (1897), Pt. V, 1183
Burlington, Racine Co., Wis.	2 1/16		Elongated tetrahedral twin		Faint greenish-white, perhaps external	?	1893 Bunde and Upmeyer, Milwaukee	Mrs. G. Pufahl, of Burlington (?)	In kettle moraine (?)	Do.	Do.
Milford, Clermont Co., Ohio	6		Octahedron (?) (Now cut into brilliant)	Markings	White	1897	1898	Two small daughters of J. R. Taylor, of Milford	In or near kettle moraine	Herman Keck, Cincinnati	Not yet described

DISTRIBUTION OF THE LAKE DIAMONDS

The localities at which the diamonds have been found are distributed throughout an area nearly six hundred miles in length by two hundred miles in breadth, with its longer axis trending almost exactly northwest and southeast. Six of the eight localities are near the center of this territory, within an area about two hundred miles square, with its center near the city of Milwaukee.

All of the diamonds, with the exception of those from Plum Creek, were obtained from the deposits of glacial drift. The Plum Creek diamonds were obtained from the bed of the stream in immediate proximity to glacial deposits. It is clear, therefore, that the stones must have reached their late resting places in the drift through the agency of the ice mantle, and we should, therefore, study the directions of glacial movement throughout the region to discover the law of their distribution and to glean any facts that may be within our reach regarding the ancestral home, or homes, which they occupied before they were carried away by the ice.

The accompanying map of the lake region (Fig. 1) is based on the glacial map of Chamberlin[1], but revised and also extended to the north so as to include the results of later studies. The moraines in the vicinity of Lake Erie have been entered from Leverett's Monograph,[2] and those southwest of Lake Superior from a map by Todd.[3] The directions of the glacial striæ have been obtained from the works of Chamberlin, Leverett, and Todd already mentioned, and from papers by Lawson,[4] Smith,[5]

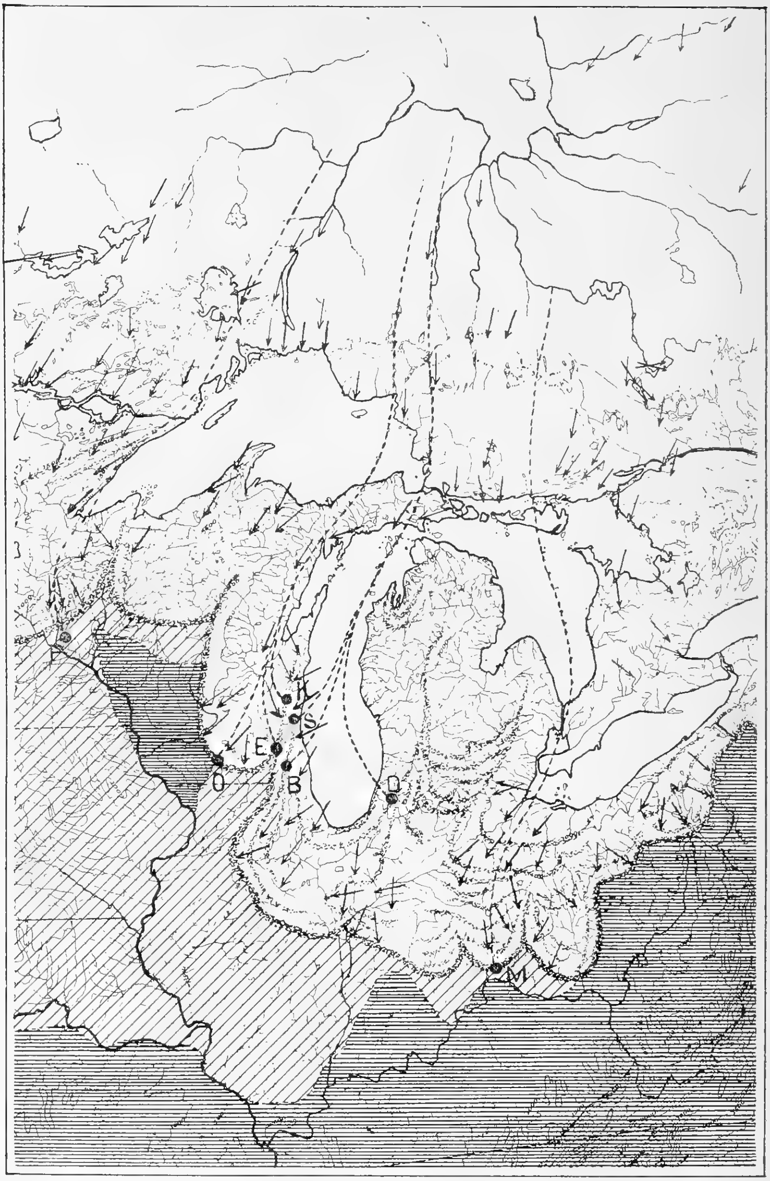
[1] T. C. CHAMBERLIN: The Rock Scorings of the Great Ice Invasions, Seventh Annual Report U. S. Geol. Surv. 1885–6 (1888), pp. 145–248, Pl. VIII.

[2] FRANK LEVERETT: On the Correlation of Moraines and Raised Beaches of Lake Erie, Am. Jour. Sci. (3), Vol. XLIII, 1892, pp. 281–301.

[3] J. E. TODD: A Revision of the Moraines of Minnesota. *Ibid.* (4) Vol. VI, 1898, pp. 469–478.

[4] A. C. LAWSON: On the Geology of the Rainy Lake Region. Geol. Surv. Can., Vol. III, 1889, Pt. I, Rept. F, Sheet No. 3.

[5] W. H. C. SMITH: On the Geology of Hunter's Island, and Adjacent Country. *Ibid.*, Vol. V, 1893, Rept. G, Sheet No. 23.



GLACIAL MAP OF THE GREAT LAKES REGION.

Driftless Areas. Older Drift. Newer Drift.

Moraines. Glacial Striae. Track of Diamonds

Diamond Localities 0 100 E, Eagle. O, Oregon.

K, Kohlsville D, Dowagiac. M, Milton. P, Plum Crk. B Burlington

Upham,[1] Low,[2] McInness,[3] and Bell.[4] In the Ohio area and in some others where a large number of observations of striæ have been collected the scale of the map has made it necessary to generalize, but these regions have been so carefully studied, both as regards moraines and scorings, that it was found easy to do this. In fact, within the territory of the United States the data at hand are sufficient for a fairly satisfactory plotting of the general direction of glacial movement at almost every point. Within the domain of Canada the great wilderness region has been covered only by reconnoissance surveys and except in the territory bordering on the lakes there exist only a few scattered observations from which to construct a map of glacial movement. In the district to the southeast of James Bay some surveys have been made but the material is not yet in print. In the region southwest and west of James Bay, which possesses also great interest, no data are available. Particularly in this latter region it is likely that striations will be found corresponding to different periods, owing to the fact that the ice from the Keewatin and Labradorean *névés* coalesced within this territory.

By plotting the diamond localities on the map it is seen that all but the Plum Creek locality are situated on the moraines of the later ice invasion, and that the latter locality is quite near to the moraine, within the area of overwash. It is also worthy of note that all but the Dowagiac stone were found in one of the marginal moraines which marked the greatest advance of the ice during its later invasion. The moraine which passes through Dowagiac corresponds to a somewhat later period, during the final retreat of the ice.

[1] WARREN UPHAM: Late Glacial or Champlain Subsidence and Re-elevation of the St. Lawrence River Basin, Am. Jour. Sci. (3), Vol. XLIX, 1895, pp. 1–18. Pl. I.

[2] A. P. LOW: Report on Exploration in the Labrador Peninsula, Geol. Surv. Can., Vol. VIII, 1896, Rept. L, p. 387, Sheets Nos. 585–588.

[3] W. C. MCINNESS: Sixth Report, Bureau of Mines, Ontario, 1896, Sheet No. 9.

[4] ROBERT BELL: Report on the Geology of the French River Sheet, Ontario, Geol. Surv. Can., Vol. IX, 1898, Rept. I, pp. 29, Sheet No. 125.

PROBABLE EXPLANATION OF THE DIAMOND DISTRIBUTION

The material from which the diamonds were derived must clearly have been to the northward beyond the lakes, in the wilderness of Canada. A method which may result in locating this material with some definiteness will be elaborated below. To explain the occurrence of so large a proportion of the stones in or near the outermost moraine, it is necessary to assume either that at the beginning of the second great advance of the ice the diamonds were embedded in a loose material easily transported, and hence largely removed before the stages of retreat, or that they were embedded in their matrix, which from its limited extent was largely abraded and removed by the ice during its initial stage.

The first is the more reasonable assumption, by reason of the wide fan of distribution of the diamonds, and the number which has been found warrants the assumption that the number of stones at the source of supply must have been very considerable. It is likely that for every diamond that has been found there are a thousand still undiscovered in the drift.

Professor T. C. Chamberlin has, at my request, very kindly given me his views on this question, and I have his permission to print the following from a personal letter:

> In regard to the explanation of the occurrence of the diamonds in the large moraines near the outer limit of the later invasion two explanations present themselves: First, the diamonds were separated from their original matrix in preglacial times by disintegration and accumulated in the bottoms of the valleys in the vicinity of their origin. The first glaciations were not sufficiently abrasive to remove the diamond-bearing gravels in the bottoms of the valleys, or at least not able to do so completely. The diamonds, therefore, do not occur frequently in the earlier drift material. Furthermore, the earlier drift material was less subjected to wash and now appears less abundantly as clean gravel and hence a less proportion of the diamonds that may have been embraced in it have been found. The chances of finding diamonds scattered throughout the till is of course relatively small.
>
> The second hypothesis postulates a sufficient interval between the earlier glacial invasion and the later to permit the disintegration of the diamond-bearing matrix and the freeing of the diamonds which became subject to transportation and accumulation in the wash from the moraines of the later drift.

This view also supposes that the glacial abrasion directly freed some of the diamonds.

Of course the two hypotheses might be conjoined and this would be reasonable enough if the diamond-bearing matrix were such as to be topographically protruding and be subjected to disintegration and wear during the interglacial interval.

Of the two hypotheses, I incline somewhat to the first, as I think it more likely that the diamonds would be accumulated in some notable quantity in the long preglacial period of disintegration than in the relatively short interglacial interval.

To me also it seems that the former hypothesis is the more probable one, for the reason given, and further, because, as will be seen from what follows, the broad fan of distribution of the diamonds would seem to require a somewhat extensive area of supply, unless it be assumed that this was very near to the "center" from which the ice moved.

THE ANCESTRAL HOME OF THE DIAMOND

The problem of locating the area from which the diamonds of the drift have been derived is a fascinating one, and, while the data now available are insufficient for its complete solution, they are of a kind to indicate that, with the increase of our knowledge likely to come in the next decade, the desired end may be reached.

The first question which naturally arises is whether all the diamonds that have been found in the lake region have been derived from a common source. While there is no certain evidence that they have, nevertheless it would seem to be probable. Diamond-bearing rocks are not so numerous that there is much likelihood of two unconnected areas being discovered in the region in question. Moreover, the occurrence of diamonds with somewhat similar crystal habits over so large a territory would seem to be significant. The Oregon, Eagle, and Kohlsville diamonds, since they were found in the Green Bay lobe of the ice mantle, a comparatively narrow area, must certainly be regarded as having a common source, and this must be, as the writer pointed out in 1894, either on the medial line of the lobe,

or still farther away to the northward. It is also fair to suppose that the Saukville, Burlington, and Dowagiac stones, though they differ from one another in habit as much as any three stones from the region, have also a common source, since they were located comparatively near to one another in the moraines of the Lake Michigan lobe. Of these latter, the Dowagiac diamond is a hexoctahedron, like the stones from Plum Creek and the closely related vicinal hexoctahedrons of Eagle and Kohlsville.

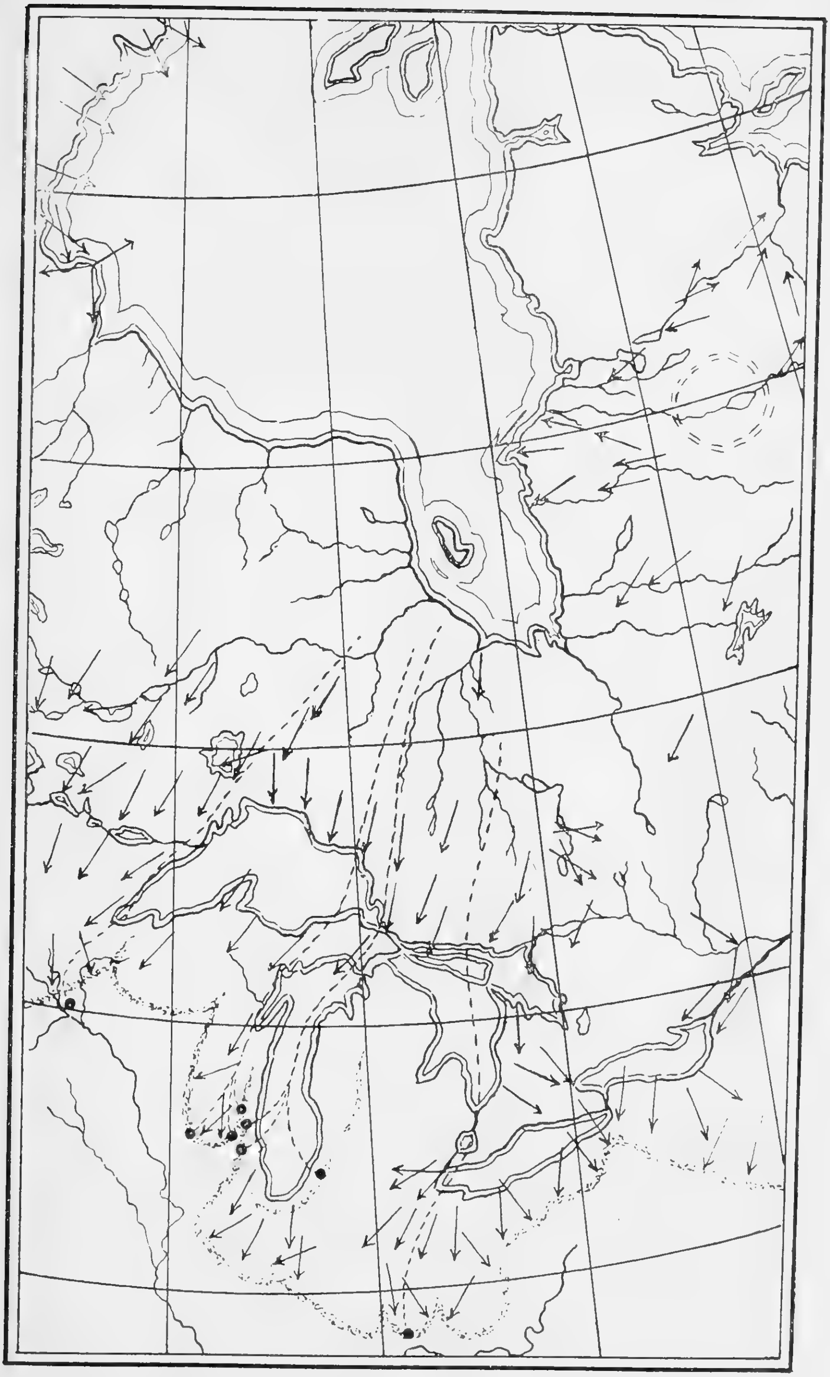
Provided a common source is assumed for all the diamonds of the region, this can only be located at the apex of the fan of diamond distribution on the hither side of the névé from which the ice moved. The wider this fan of distribution is found to be, the nearer is its apex carried towards the ice summit. The radial sides of the fan must be largely determined from the directions of striæ within the Canadian wilderness, of which an adequate number have been recorded only from the immediate vicinity of the Great Lakes. Beyond these borders the *tracking* of the diamonds can be carried out only with a certain approximation to correctness.

One of the results of the magnificent investigations of Tyrrell[1] and Low,[2] the one working to the west and the other to the east of Hudson Bay, has been the location of two main "centers" of the ice mantle corresponding to the Keewatin and Labradorean or Laurentide glaciers. The eastern of these "centers" or névés, and the one which must have principally affected the glaciation of the area of the Great Lakes, has been located by Low to the east of James Bay, a little to the eastward of the present watershed on the Labrador peninsula. This is brought out on the accompanying map (Fig. 2) by the directions of the striæ of this vicinity.

The tracks of the lake diamonds which have been delineated upon the map, converge in the direction of this névé, and show

[1] J. B. TYRRELL: Report on the Doobaunt, Kazan, and Ferguson Rivers, and the northwest Coast of Hudson Bay, Geol. Surv. of Can., Vol. IX, 1896, Report F, pp. 1–218.

[2] A. P. LOW: *loc. cit.*



GLACIAL MAP OF THE TERRITORY ABOUT HUDSON BAY AND THE GREAT LAKES.

that the apex of the fan of diamond distribution probably lies somewhere in the strip of territory bordering James Bay on the east.

DATA NEEDED TO DEFINITELY LOCATE THE SOURCE OF SUPPLY OF DIAMONDS

Before the home of the diamonds can be located with definiteness, it will be necessary to carry out several lines of investigation. Of first importance is it that the direction of ice movement be studied in as much detail as possible in the territory surrounding Hudson Bay on the southwest, south, and east. It will be important also to search the moraines south of the lakes, and particularly the marginal ones, for diamonds, since the evidence points to them as the principal repository of the emigrated stones. It is especially important to examine the moraines of Ohio, western New York and western Pennsylvania, in order to determine whether the fan of distribution extends farther in that direction. If this is true, the apex of the fan would seem to be located very near to the center of the Labradorean névé.

It has seemed to the writer that much might be gained by arousing an interest in the problem in the people who reside on or near the moraines, and suggesting to them that children particularly be urged to use their keen eyes in search for the diamonds that have been sown in the drift. To this end a brief statement has been prepared which sets forth what has already been learned regarding the lake diamonds, and explaining how rough diamonds may be distinguished from the ever present quartz pebbles. For identification of stones the persons finding them are referred to mineralogists, who are competent to pass upon gem stones, and who are willing to do so without compensation because of their interest in the problem. It is hoped that the editors of local newspapers in the morainal belt, to whom the statement will be mailed, will be willing to coöperate by printing it, and thus aid materially in disseminating the needful information. WM. H. HOBBS.

REPLACEMENT ORE DEPOSITS IN THE SIERRA NEVADA

It is well known that most of the gold deposits of the Sierra Nevada occur in true fissure veins in which the quartz appears to have been deposited in open cracks. This has been emphasized recently in a very clear manner by Mr. Waldemar Lindgren in two papers,[1] and he has also shown that the material of these veins was deposited by carbonated waters containing also silica and the precious metals. These waters have deposited their carbonates in very definite zones in the wall rocks, and the silica in the fissures. At some points, however, in the Sierra Nevada there are ore deposits which seem to have formed by the replacement of other material. Such appears to be the Diadem lode[2] southwest of Meadow Valley in Plumas county. This lode seems to represent a mass of dolomite and lime carbonate which has been replaced by quartz and chalcedony; masses of dolomite are still found on some of the levels. Iron and oxides of manganese are present, and according to J. A. Edman rich selenides of gold and silver combined with lead and copper occur as a rarity. Some of the manganese is in the form of the silicate, rhodonite. A certain portion of the lode is composed of little elliptical bodies which according to Mr. Charles Schuchert of the U. S. National Museum represent the silicified tests of foraminifera of Carboniferous age belonging to the genus Loftusia. The shells of Loftusia were originally carbonate of lime. These fossils were found by Mr. J. A. Edman, the proprietor of the mine, and forwarded to the Geological Survey for determination. They sometimes form considerable bunches, the interspaces between the elliptical tests being filled with secondary silica, or in some

[1] Bull. Geol. Soc. of America, Vol. VI, pp. 221–240.

Gold Quartz Veins of Nevada City and Grass Valley, Seventeenth Ann. Rep. U. S. Geol. Surv., Part II.

[2] See Bidwell Bar folio of the U. S. Geol. Survey.

cases being open. Other specimens of a fine-grained red siliceous rock which forms part of the lode, appear to represent a calcareous shale subsequently silicified. The red rock contains very abundant bodies, smaller than the Loftusia determined as such, but probably also of foraminiferal origin. Whatever the original nature of these smaller tests, they are now composed of granular quartz like the Loftusia. There is here unequivocal evidence that a considerable mass of carbonates has been replaced by silica. A large portion of the vein material containing the precious metals of the Diadem lode is chalcedony. The same waters which deposited the quartz and chalcedony and replaced the carbonates of the foraminifera tests are without doubt responsible for the gold, silver, manganese, etc., found in the deposit. This vein deposit may therefore be called a replacement deposit. The Diadem lode lies in the fault zone along which displacements have formed the steep slope east of Spanish Peak. There is also evidence of faulting in comparatively recent times at the lode itself.[1] It is without doubt along these faults that the waters containing the silica, etc., of the deposit have found their way from below. Such being the case it is likely that a certain portion of the secondary material may represent a true vein deposit, but it is probable that the larger part of the lode, which is represented by Edman as being in places sixty feet wide, may be called a replacement.

Professer Whitney inclined to the belief that the great quartz veins of the mother lode represent the replacement of bodies of dolomite. As Lindgren remarks,[2] however, this theory has not been supported by more detailed investigation. H. W. Fairbanks has suggested that these very large veins of pure quartz, sometimes forty feet in width, have resulted from the replacement of dikes of basic igneous rocks. The mechanical difficulty of accounting for the existence of such wide fissures, and the fact that the vein matter in these large masses seldom shows a banded structure such as might be expected from the deposit of

[1] Seventeenth Ann. Rep. U. S. Geol. Surv., Part I, p. 553.

[2] Bull. Geol. Soc. Am., Vol. VI, p. 235.

successive layers of quartz in an open space, are urged by Fairbanks as difficulties in the way of calling these veins filled-in fissures. The gradual replacement of the constituents of dike rocks by the vein material would perhaps account for the great size of the veins as well as their lack of banded structure. However, quite recently Lindgren[1] has brought forward a point as to the different character of the silica deposited as replacement material by a metasomatic process and that deposited in open spaces, which may serve as a criterion to determine, with the aid of the microscope, the two classes of deposits. Lindgren, after referring to the strong solvent nature of carbon dioxide and of alkaline carbonates, and the inert character of silica as a solvent, writes:

Silicification by the cementation of shattered rock masses by silica is, of course, a common occurrence in and near quartz veins. But silicification by replacement is a less common process, and is observed chiefly in the case of easily soluble rocks, such as limestone or calcareous shales, when it results in fine-grained or cryptocrystalline aggregates of silica. In the metasomatism of bodies of massive rocks penetrated by chemically active solutions silica is formed in many ways, as by the carbonatization of silicates and sericitization of the feldspars, and if no open spaces are available much of this free silica will be deposited within the rock, usually as fine-grained aggregates more or less mixed with opal and chalcedonite. If no material were added the final result of this would not, however, be a silicification, but merely an increase in the total free quartz of the rock. But in case the rock mass is cut by fissures it appears that most of the resulting free silica is not deposited in the rock, but finds its way out in the open ducts, where, if the solution is supersaturated, it will be deposited. . . . .

As for the other possible process of silicification, or a dissolving of the original mineral and a deposition of silica *pari passu*, it occurs chiefly in easily soluble minerals, such as calcite. In case of the ordinary rock-forming silicates it is apparently not common. The resulting silica is generally in the form of fine, cryptocrystalline aggregates. Rocks silicified by either of these metasomatic processes, or by a combination of both, may occur, but, so far as the writer's experience goes, are not often encountered as wall rocks of auriferous quartz veins. But neither of these processes can have produced the massive, white, coarse-grained quartz of gold veins belonging to the normal type. This quartz, which contains native gold and sulphides, shows,

[1] The Mining Districts of the Idaho Basin and the Boise Ridge, Idaho, Eighteenth Rep. U. S. Geol. Surv., Part III, p. 645.

under the microscope, a peculiar, coarsely granular structure, the grains being partly bordered by crystallographic surfaces. This structure could have been developed only by free crystallization in open spaces. It is scarcely necessary to call attention, in addition, to the frequency of comb structure, etc., proving also the same kind of origin. This does not necessarily mean that all large bodies of quartz have been deposited in an open space, as large as the volume of quartz now is. Repeated openings of the fissure have doubtless often taken place.

Lindgren's results as to the usually finely granular character of the quartz deposited as a replacement are borne out in the Diadem lode occurrence, as may be seen by an inspection of Plate V on which are represented two photomicrographs, one of a thin section of the red siliceous rock of the Diadem lode without the analyzer, in which may be seen the outline of one of the elliptical bodies previously referred to as being probably of organic origin, and the other exactly the same view with the analyzer, in which the finely granular character of the quartz is shown. No careful microscopic examination of the quartz of the large massive veins of the southern part of the lode has, so far as I know, been made. Three thin sections from the croppings at the Peñon Blanco mine in Mariposa county (see Sonora folio) show that considerable patches of the quartz have the same optical orientation throughout, indicating large crystals and consequently deposition in an open space. It appears, therefore, likely that the huge quartz masses, some of them twelve meters in width, were deposited in open fissures and are not replacement deposits. The large size of the masses of quartz having apparently the same optical orientation throughout and the lack of banding may indicate merely quiet conditions during deposition and lack of interruption of the process.

To certain masses that form portions of the Mother lode a somewhat different origin must be assigned. I refer to the oft-described deposits composed of quartz, and calcium and magnesium carbonate, and mariposite. Lindgren considers[1] that these large masses represent nothing but altered serpentine, and asserts that abundant transitions may be found to prove this, as may

[1] Bull. Geol. Soc. Am., Vol. VI, p. 235.

be plainly seen at the App mine at Quartz Mountain in Tuolumne county. He considers this conversion readily explained when it is considered that serpentine is easily decomposed by carbonated waters into magnesite and chalcedonic quartz. In this case, as with the fissure veins, the essential feature is the introduction of the carbonated waters, and in confirmation of this may be cited the composition of this peculiar alteration product as given later in the table (Analysis No. 1508). The atomic composition of this rock is quite similar to the atomic composition of serpentine with the addition of carbon dioxide; while the difference in mineral composition is very striking, the original serpentine being a silicate and the alteration products carbonates. Such a deposit cannot be called a vein and it is likewise from the above standpoint not a replacement deposit, for the original elements are largely still there but in new combinations. There are some facts which will now be presented which at first glance suggest that the quartz, carbonate and mariposite deposits above described have not originated from the alteration of serpentine in place, but have resulted from the metasomatic alteration of dikes rich in soda, and hence may be called replacement deposits.

Lying just east of Moccasin Creek[1] in Tuolumne county, is a white dike which extends from the mouth of the creek in a southeasterly direction. The larger portion of the dike lies east of the creek and crosses the road to Priest's about 0.6 kilometers east of the bridge over Moccasin Creek. This dike has been rather fully described in a previous publication.[2] It is composed largely of soda-feldspar or albite, with quartz and muscovite locally abundant. A green aegerite-like mineral, and radial tufts of bluish amphibole are likewise present at some points. Throughout the greater part of its course the dike is bordered by serpentine on the west and greenstone on the east.

At numerous points this dike has been exploited for gold. Some of it is plainly mineralized, containing specks of iron

[1] See Sonora folio of the Geological Atlas of the U. S.

[2] Seventeenth Ann. Rep. U. S. Geol. Surv., Part I, p. 664.

pyrite. The rock is often very white and hard and is called quartz by some of the miners who are exploiting it. Three samples of this soda-feldspar dike from the Wheeler and Hill claim were assayed with the following results:

ASSAYS OF THE SODA-FELDSPAR DIKE OF THE WHEELER & HILL CLAIM

	2005–A	B	C
	Ounces	Ounces	Ounces
Gold	0.10	0.02	none
Silver	0.15	0.12	none
Authority.......	C. E. Munroe	Selby & Co.	Selby & Co.

The gold and silver and the iron pyrite appear to be disseminated through the dike rock, for no little veinlets are to be noted in the specimens assayed, as is the case in some of the mineralized soda-feldspar dikes. At the Black Warrior mine on the Moccasin Creek dike there has been reported a valuable deposit of workable ore since the date of my visit (1897). In the tunnel of this mine a mineralized talc streak in serpentine contains sulphides of iron and gold and silver. As to whether the valuable ore body is in the dike rock or not I have no reliable information.

Along Kanaka Creek about 2 km east of Jacksonville is another soda-feldspar dike which is nearly in a line with that east of Moccasin Creek. This is likewise mineralized at several points. At the Willietta mine on the Kanaka Creek dike a considerable mass of the dike rock has been quarried out and treated as ore. This deposit was examined by a San Francisco mining engineer, Mr. Luther Wagoner, and I am indebted to him for the following information: About 3000 tons of the rock were milled; the top two or three feet of the dike yielding about $3 per ton. Subsequently Mr. Wagoner made a mill test of a face fifteen feet high, this containing about 78 cents per ton in gold. Another sample of thirty tons yielded 56 cents per ton in gold. The concentrates (probably chiefly iron pyrite) were found to

be quite poor, showing only about $14 per ton. The gold seems to lie largely along the seams and joints of the mass. The unweathered dike rock carries about ½ per cent. of pyrite in little cubes from 0.5 to 1 mm in diameter.

In Eldorado county similar dikes form the lodes of gold deposits. Two of these have been worked with some profit.[1] The claims are known as the Shaw and Big Canyon (Orofina) mines, and are indicated on the economic geological map of the Placerville folio. My attention was first called to the Shaw mine lode by Mr. Leo von Rosenberg who transmitted specimens of the rock showing the porphyry dike rock, and other specimens containing veins of quartz and veins of albite with free gold. The dike rock of the Shaw mine and also that of the Big Canyon mine contain iron pyrite rather abundantly in places. Calcite is scattered through the dike rock in little rhombs. The evidence at the Shaw and Big Canyon mines is that mineral waters have percolated through the dike rock and deposited the iron pyrite and calcite with some gold throughout portions of the dike, while the quartz has largely been deposited in little veins along with most of the gold. The veins of white albite in the Shaw mine rock are undoubtedly secondary, but probably represent the material of the dike leached out and redeposited. This in itself suggests that albite is a mineral which is readily dissolved, and Lindgren has found sodium one of the elements most readily removed from the wall rocks of quartz veins.

The Bachelor lode on the north bank of the Tuolumne River lies at the contact of a mass of serpentine with a lens of argillite supposed to belong to the Calaveras formation. Just east of the vein, in the clay schists within a width of thirty feet, are six or eight dikes, which usually run parallel with the strike of the schists, but at two points cut across the schistosity. Such a series of dikes might be called a multiple dike, following

[1] Am. Jour. Sci. Third Series, Vol. XLVII, 1894, pp. 470–471.

Engr. and Mining Jour., Nov. 19, 1892, article by C. A. AARON on the Shaw mine lode.

Am. Geol. Vol. XVII, 1896, p. 380.

KEMP, Ore Deposits of the U. S., New York 1896, p. 287.

Lawson,[1] as it is reasonably certain that at some depth below the surface they all come together. The dikes vary from two inches to two feet in width. Quartz veinlets, one with a convoluted course, cut both the schists and the dikes. Between the dikes and the ledge is a broken-up mass of the dike rock of a reddish-brown color, penetrated by quartz veinlets and seams of dolomite, and apparently in a fair way to form a lode, like that immediately west, if the alteration should go farther. This mass seemed a friction breccia and would indicate movement and faulting along the lode. A microscopic examination of this breccia showed it to be made up of fragments of the dike rock cemented by dolomite and quartz. Throughout the rock, as well as in the dikes just east, is scattered iron pyrite in minute specks. The brown color is due to abundantly disseminated limonite. The microscope shows the dike rocks, where not replaced by silica and carbonate, to be composed almost entirely of interlocking grains of soda-feldspar with some larger twinned feldspars, in fact identical as to composition with other similar soda-feldspar dikes. There thus seemed to be evidence here that the dike rock has undergone replacement. To determine what alterations had taken place in the dikes some partial chemical analyses were made as follows:

PARTIAL ANALYSES OF SODA-SYENITE AND ITS REPLACEMENT ALTERATIONS BY DR. H. N. STOKES

	No. 1521	No. 1509	No. 1512	No. 1508
SiO_2	67.53	52.83	42.48	37.58
$CaCO_3$	none	9.64	13.43	5.78
$MgCO_3$	none	7.38	8.17	46.82
$FeCO_3$	none	.98	5.88	6.35
FeS_2	....	.77	.40	none
K_2O	.10	.35	2.67	0.23
N_2O	11.50	7.87	4.79	trace
Residual CO_2	none	.59	2.23	2.45

[1] American Geologist, Vol. XIII, p. 293.

Dr. Stokes states that the residual CO_2 is the excess above that required for $CaCO_3$ and $MgCO_3$, and is in 1508 at least clearly present as $FeCO_3$. Assuming the residual CO_2 is in the form of $FeCO_3$ in 1509 and 1512 also, I have calculated the amount of this in each case and inserted it in the analysis. The analysis as completed by Dr. Stokes contained no estimate of the $FeCO_3$.

No. 1521 is a specimen of the Moccasin Creek dike, and composed of nearly pure soda-feldspar. The rock contains no carbonates.

No. 1509 is from one of the soda-feldspar dikes in argillite just east of the Bachelor mine deposit.

No. 1512 is a more altered specimen of the soda-feldspar rock from another branch of the multiple dike of the Bachelor mine.

No. 1508 is the Bachelor lode material itself, composed of quartz, carbonates, and mariposite.

In this series there is the clearest evidence of a diminution of silica and sodium and an increase of carbonates from the fresh dike rock represented by No. 1521 to the lode material represented by No. 1508. There is, however, a decided jump in the magnesian carbonates in Nos. 1509 and 1512, which are certainly altered soda-feldspar dikes, to the magnesian carbonate in the lode material 1508. There being a mass of serpentine immediately west of the lode, and magnesium being readily soluble in carbonated waters, no one will doubt that the magnesium, both in the lode and in the dikes, came orginally from the serpentine. The possibility therefore arises that the association of the dikes and the carbonate lode is merely accidental. In that case we are forced to adopt Lindgren's hypothesis as to the origin of the lode itself, and to suppose that the alteration of the dikes is merely due to its proximity to the lode, itself formed by the alteration of serpentine. A case entirely similar is that of a mass of shale adjacent to serpentine. An analysis of the shale next to the serpentine may show a decided content of magnesia, but this does not prove the origin of the serpentine from the shale, but merely that waters charged with magnesium

from the serpentine have soaked into the shale and deposited their burden.[1] The above facts cannot be regarded as evidence that the Bachelor lode has formed from the replacement of a soda-feldspar dike, but it gives conclusive evidence that such dikes readily undergo replacement when permeated by mineral waters. The soda-feldspar dikes occur very often in association with serpentine. This is the case in Plumas and Butte counties, where, however, no evidence of mineralization was noted. It is also the case at the Big Canyon mine, Eldorado county, and at the Willietta, Bachelor, Black Warrior, and Wheeler and Hill mines in Tuolumne county, and at various points north of the Merced River in Mariposa county. The dikes are not confined to the serpentine, however, although, so far as I know, they are nearly always in the neigborhood of this rock. One dike, however, more than a kilometer in length was noted in the sediments of the Calaveras formation, the nearest mass of serpentine being four kilometers distant. Open cuts at numerous points indicated that this dike had been prospected for gold. There is also a syenite dike in the slates of the Mariposa formation by the tollhouse west of Princeton, along which are small quartz veins. This dike is likewise mineralized, containing lime carbonate very abundantly and pyrite. At the Shaw mine also the dike is in slates, probably of Carboniferous age. The usual association of the dikes with serpentine suggests an original genetic connection,but this has nothing to do with the mineralization of the dikes, which takes place irrespective of the immediate presence or absence of serpentine, although it is possible that magnesium carbonate is never present to any extent except when serpentine is immediately adjacent. The association of gold with soda-feldspar dikes, so far as my observation goes, is more frequent than with dikes of other rocks, and this may point to albite being a mineral more readily altered or replaced by mineralizing solutions than any other feldspar. Experiments have been made on the relative solubility of some of the feldspars in pure water and in water charged by carbon dioxide. Mr. George Steiger kept for one month one half grain

[1] For definite examples of this see Bull. Geol. Soc. Am., Vol. II, pp. 406–408.

of three powdered feldspars separately in 50 cm^3 distilled water, at 70° F., with the following results:

	Percentage of alkali dissolved
Orthoclase - - - - - - - -	0.16 K_2O
Albite (Amelia Co., Va.) - - - - - -	0.07 N_2O
Oligoclase (Bakersville, N. C.) - - - - -	0.09 N_2O

This would show a greater solubility for orthoclase than for albite, but it is more to the point to observe the relative solubility of the feldspars with water charged with carbon dioxide. R. Müller[1] obtained the following results:

SOLUBILITY OF METAL OXIDES OF FELDSPARS IN CARBONATED WATER

	SiO_2	Al_2O_3	K_2O	N_2O	CaO
Orthoclase (Adular)	.1552	.1368	1.3527	....	trace
Oligoclase	.237	.1713	....	2.367	3.213

It is clear here that the soda of the oligoclase is more soluble than the potash of the orthoclase, and that the lime of oligoclase is more soluble than the alkali. No quantitative statement of the solubility of pure albite in carbonated waters has been noted. The apparent readiness with which the albite of the dike rocks described in the paper goes into solution and is again deposited as albite in cracks, seems certainly to indicate that under certain unknown conditions this mineral is readily soluble.

Dr. Becker[2] describes the Treadwell mine on Douglas Island in Alaska as being an impregnation of a dike of sodium syenite, which has been mineralized in apparently exactly the same way as the sodium syenite dikes of the Mother lode above described. Becker states that the Treadwell syenite is composed chiefly of albite with subordinate amounts of soda-lime-feldspar, augite, amphibole, and biotite.

The ore associated with the syenite is separable into two distinct varieties. Of these one consists of stringers of quartz carrying some calcite and occupying interstitial spaces between more or less decomposed syenite fragments.

[1] Braun's Chemische Mineralogie, 1896, p. 398.

[2] Eighteenth Ann. Rep. U. S. Geol. Surv., Part III, p. 38 and p. 64.

In such ore the pyrite is often grouped in bunches and at other times is desseminated through the quartz. The distribution of the pyrite seems to be without effect upon the tenor of this variety of ore, which is usually rich in proportion to the quantity of pyrite. The other variety of ore consists of fragments of the syenite which have been, as it were, *soaked* in the auriferous liquid. They are impregnated chiefly with carbonates and pyrite, only a little silica penetrating where there were no open fissures. The pyrite in this variety is also either bunched or disseminated, and all the mine foremen assert that where this pyrite is scattered, the ore is nearly or quite worthless. It appeared to me that the disseminated pyrite represents ferromagnesian silicates attacked by sulphydric acid or soluble sulphides, and study of the ore under the microscope lends strength to this hypothesis, though without absolutely proving it.

Wherever the ore is strongly mineralized the ferromagnesian silicates have totally disappeared from the syenite, and the pyrite is scattered in it in about the same manner as the iron-bearing silicates in the fresher material. On the other hand, as the bunches of pyrite are accompanied by much calcite they could not have been produced from any ordinary accumulation of ferromagnesian silicates, and I think such pyrite must have entered the rock in a state of solution.

The alteration of the soda-feldspar dikes seldom or never goes so far as to constitute a complete replacement of the original material, and the ores are, so far as I know, uniformly of low grade. Such ore deposits may perhaps be called *partial replacements*. According to Lindgren [1] the term *substitution* is sometimes used for deposits of this character. In a paper on the auriferous veins of Meadow Valley [2] Lindgren describes the alteration of granodiorite along fractures by solutions containing heavy metals and boron. The deposits consist of epidote, zoisite, pyroxene, tourmaline, quartz, mica, titanite, ilmenite, calcite, and auriferous sulphides. These lodes seem to be of the nature of replacements.

H. W. TURNER.

PLATE.

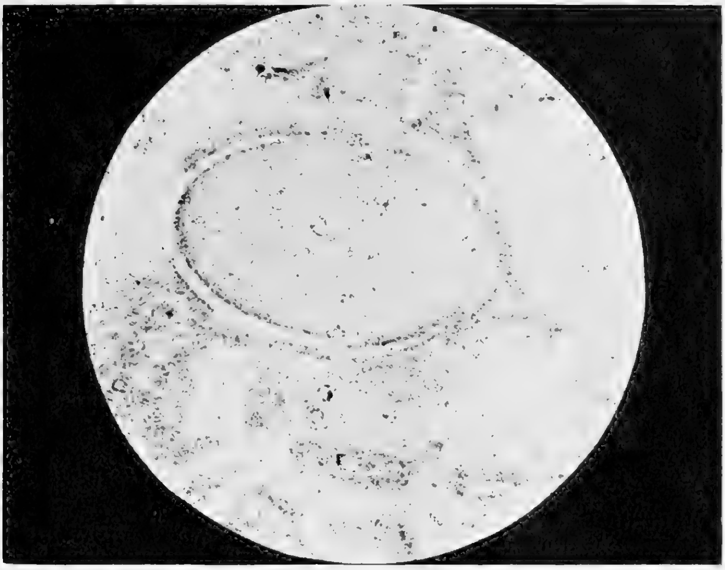
A. Photomicrograph of thin section of the red silicified shale of the Diadem lode, showing the outline of a foraminiferal test, without the analyzer, $\times$ 29.

B. Photomicograph of same view of thin section of red silicified shale as last, but taken with the analyzer, $\times$ 29.

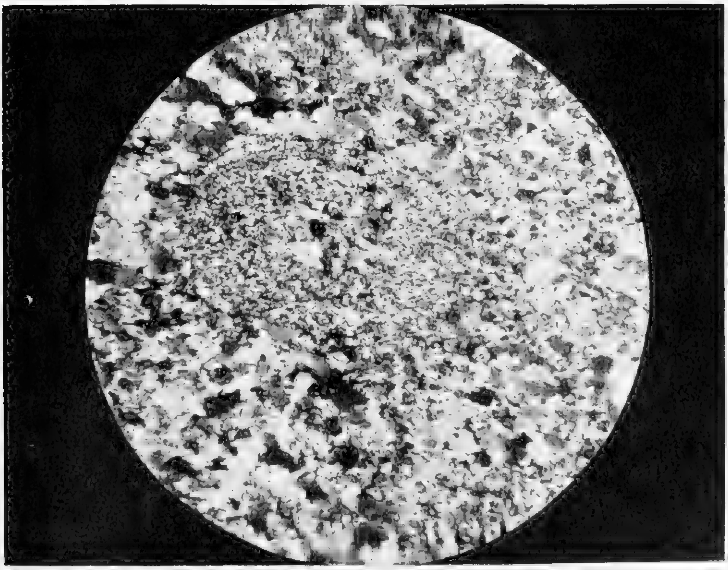
The two photographs by J. V. Lewis.

[1] Stanford University Engineering Journal, February 1898, p. 10.

[2] Am. Jour. Sci., Vol. XLVI, 1893, p. 201.



A × 29.



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EDITORIAL

Othniel Charles Marsh has left for himself as conspicuous a name and fame as could be desired by the most ambitious student of science. He had the advantages of a strong constitution, a clear intellect, indefatigable industry, a liberal fortune, a love of nature and the beautiful, a single purpose, and had no one dependent upon him for a share of his devotion. He began life in Lockport, New York, in October 29, 1831; as a boy was fond of hunting and fishing and out-door life; went to Phillips Andover Academy in 1852, graduated in Yale College in 1860, and took two more years of graduate work in the Sheffield Scientific School. In those days he was chiefly interested in chemistry and mineralogy. Then he went to Europe, where he spent three years studying mineralogy and paleontology, and in 1866 was appointed professor of paleontology in Yale University. From that time to the day of his death, March 18, 1899, he was devoted to original research, chiefly in the accumulation and study of fossil vertebrates, and to the building up of the Peabody Museum at Yale University, to which he gave at the close of his life all his collections and the great bulk of his fortune.

The contributions Professor Marsh made to science during his busy life are chiefly remarkable for the large number of startling new types of fossil vertebrates which he either first announced or brought to conspicuous notice by the number and perfection of the specimens representing them. His earlier investigations were in the Cretaceous deposits of the East; but his most remarkable discoveries were in the Jurassic, Cretaceous, and Tertiary beds of the Rocky Mountain regions, and in the plains east of them. In this latter region he conducted several expeditions of Yale students or graduates; and after the fossil-bearing beds were discovered, employed many collectors for

repeated years in digging out and shipping to the East the immense and rare bones, which were carefully worked out after reaching the Museum.

A bare list of the more important types of vertebrates, which he either first discovered or first elaborated, is of itself enough to exhibit the great place his labors must occupy in the progress of science.

In 1862, he announced the discovery of the Enaliosaurus in the Carboniferous rocks of Nova Scotia—a large Amphibian with biconcave vertebræ. It was Marsh who, in 1868, disputed the organic nature of Paleotrochis; and in the same year the metamorphosis of the Siredon was described. Fossil birds were discovered in both Tertiary and Cretaceous rocks, in 1870. The Rocky Mountain expedition of 1870 resulted in the discovery of the *Mauvaises Terres* formation in Colorado. In 1871, fossil serpents were reported from the Tertiary deposits of Wyoming, and a gigantic Pterodactyl from the Cretaceous of Kansas. In the following year Hesperonis, the wonderful bird with teeth, was announced, and the skull and limb bones of the Mosasaurus, the skeleton of Tinoceras, and remains of Quadrumana from the Eocene of Wyoming described. In 1873, new species of Ichthyornis, another toothed bird, were described, and a new subclass, Odontornithes, was founded, establishing the link between Birds and Reptiles. And the new order Dinocerata, with many enormous species, was defined and elaborated. In 1874, another expedition was conducted to the Rockies, and the Brontotheridæ were fully defined, and the fossil horses and their ancestors of the Tertiary were described. Also, a paper was written illustrating the small brain capacity of the early Eocene mammals. In 1875, a new order of Eocene mammals was announced, and an important statement of the affairs of the Red Cloud agency was made to the President.

In the following year the characters of the Dinocerata, the Tillodontia, the Brontotheridæ, the genus Coryphodon, and a new suborder of Pterosauria, were elaborated in important papers. In 1877, wonderful Dinosaurs from the Jurassic were

brought to light; and in 1878, new species of Ceratodus, of Dinosaurs, and of Pterodactyles were described. The next year he described another new order, the Sauranodonta from the Jurassic of the Rocky Mountains, and wrote the paper on Polydactyl horses, recent and fossil, setting forth in brief the history of the horse ancestry. The monograph on the Odontornithes was published in 1880. Numerous papers followed as the great and peculiar types of Dinosaurs were worked out; the Stegosaurus, the Brontosaurus, the Ceratopsidæ, Triceratops, etc.; and in 1896, an elaborate report on the Dinosaurs was published as a part of the Sixteenth Annual Report of the United States Geological Survey, not in the form of a monograph. In 1884. the skull of Pteranodon, the Pterodactyl without teeth, was elaborated, and the monograph on the Dinocerata, the gigantic extinct order of mammals, was published.

During the last ten years of his life, although there were fewer great discoveries to announce, the papers in elaboration of the immense accumulation of materials illustrating fossil vertebrates appeared in rapid succession; over one hundred titles having been added to the list of his published papers during these years. Among the more important contributions during this period were his discussions of the relations of *Pithecanthropus erectus;* on the age of the beds on the Atlantic coast which he called Jurassic; and important additions to knowledge of Dinosaurs, Tertiary and Cretaceous mammals, birds, fossil footprints; the description of a new Belodont reptile from the Connecticut River sandstone; and on sundry other subjects.

Professor Marsh was honored by election to membership and office in the principal societies and academies devoted to science in this and other countries. He was for two terms President of the National Academy of Sciences, and in 1897 received the Cuvier prize from the Institute of France. In 1886, he received the honorary degree of Ph.D. from the University of Heidelberg.

He died in the midst of active work. The manuscript for several other monographs on fossil vertebrates was left unfinished. Besides the large collections accumulated at his own

expense, which he had turned over formally to Yale University before his death, he left a large amount of material belonging to the United States Geological Survey, which had been collected under his direction and was undergoing description. It is probably true that no other one man has ever accumulated such a vast collection of remarkable and well preserved fossil vertebrates.

H. S. W.

Mr. Thomas Jones has recently completed a reduction of his model of the earth which possesses sufficient merit and is of sufficient interest to geologists to warrant notice. The vertical exaggeration of his former globe was 36 to 1. The present is a reduction to 18 to 1. This relieves the exaggeration of most of its objectionable features and still leaves the relief impressive enough for lecture-room purposes. The first copy made has now been in use by the writer for several weeks with satisfactory results. The hypsometric data given by the Challenger Report have been followed for the oceanic basins.

T. C. C.

To meet an expressed desire for advanced summer courses in the fundamental principles of geology and glaciology suited to college teachers and advanced students, two courses will be offered during the first term of the summer session, July 1 to August 1, at the University of Chicago by Mr. Chamberlin. The first will consist of a discussion of basal questions and unsolved problems in geology taken up in historical order, so as to constitute in some measure a review of geological history. Following the method of multiple working hypotheses these questions will be discussed in the light of alternative theories. Some special attention will be given to a new series of hypotheses based upon the slow growth of the earth by meteoroidal accretions, these hypotheses being of such a nature as to develop with peculiar facility the strength and weakness of existing hypotheses and

to open up the problems widely. The atmospheric and climatic factors will receive special attention, as will also the reciprocal development of land and sea periods, the conditions of expansional, restrictional, and provincial life evolution, and the special functions of base-leveling, sea-shelves, epicontinental seas and atmospheric changes in controlling life progress.

The course in glaciology will embrace a discussion of the physics of glaciers, their chronological development, the distinctive phenomena of glacial deposits, and their interpretation.

The two courses will run parallel. They are only offered for the coming summer.

Besides these, the usual courses in physiography, meteorology, general and structural geology and field work will be offered by Professor Salisbury, assisted by Messrs. Goode, Atwood, Calhoun, and Finch.

ERRATUM

On p. 225 of the current volume, for "The glacier on Mount Iztacciahuatl is advancing" read: the glacier on Mount Iztacciahuatl is retreating at the rate of about two meters a year. H. F. R.

SUMMARIES OF CURRENT NORTH AMERICAN PRE-CAMBRIAN LITERATURE.[1]

SMYTH[2] reports on the crystalline rocks of St. Lawrence county, and particularly the towns of De Peyster, De Kalb, Hermon, Edwards, Canton, Russell, Potsdam, Pierrepont, and Parishville; together with points reëxamined in the towns of Gouverneur, Rossie, and Fowler, which were covered in the examination made during 1893. The crystalline limestones, for which, in a previous report, the name Oswegatchie series was suggested, form belts stretching in a northeast-southwest direction. Four belts comprise a large proportion of the crystalline limestones of the region examined. The largest, the Gouverneur belt, extends from Antwerp to probably two miles south of Canton village. Northwest of this belt another belt extends from Theresa, across Rossie and Macomb, into De Peyster. This belt is perhaps separated from the first belt by narrow strips of gneiss, along the northern boundary of Gouverneur, although the precise extent of the gneiss belts is undetermined. The third belt, the Edwards belt, to the south of the Gouverneur belt, and separated from it by a belt of gneiss, begins in Fowler, crosses Edwards, and runs out in the western part of Russell. The fourth belt, the Diana belt, south of the Edwards belt, and separated from it by gneiss, crosses the towns of Pitcairn and Diana. In general, the limestones have their greatest development in the northwestern part of the region, decreasing as the eastern and southern parts of the district are approached.

The limestone is everywhere thoroughly crystalline, ranges in color from white to dark bluish-gray, and often contains disseminated and aggregated silicates, of which the more important are serpentine and tremolite.

The term gneiss is used to include rocks ranging from acidic to basic, from fine to coarse grained, and from distinctly gneissoid, or even schistose, to entirely massive. They constitute a complex series,

[1] Continued from page 205, Vol. VII., JOUR. GEOL.

[2] Report on the crystalline rocks of St. Lawrence county, by C. H. SMYTH, JR.: From the Fifteenth Ann. Rept. State Geologist, in Ann. Rept. of N. Y. State Museum, 1895, pp. 481-497.

of rocks, differing somewhat in age, and largely, if not almost wholly, of igneous origin. Parts of this series are clearly younger than the limestones; other parts may be older than the latter formation, but there is nothing as yet to prove that such is the case. A probable exception to the latter statement is afforded by certain laminated gneisses, of limited extent, which appear to underlie the limestone, perhaps marking the base of the series.

Many of the gneisses have heretofore been believed to be sedimentary, and the evidence leading to the conclusion that they are largely igneous may be briefly summarized: There is the negative evidence of the absence of all structures pointing to sedimentary origin; the uniformity of composition and structure over wide areas, with changes by gradual transition; a common occurrence of massive cores, in every way identical with plutonic rocks; the presence of structures in the gneiss that would result from the application of pressure to igneous rocks; eruptive contacts between the abundant light-colored gneiss and the less common and older dark gneiss, together with widespread instances of inclusions of the dark gneiss in the light; the identity of the gneiss near Natural Bridge with the plutonic gabbro intrusive in the limestone; eruptive contacts at a number of places of the gneisses with the limestone.

Cushing[1] describes syenite-porphyry dikes in the northern Adirondacks. They are shown to be of pre-Cambrian age, but later than the gabbros and granites of the region. The syenite-porphyries constitute the complementary rocks to the diabases of the region, and together with them form an eruptive assemblage similar to that which characterized Keweenawan time in the Lake Superior region.

Cushing[2] describes the geology of Clinton county, New York. The pre-Cambrian succession, following Kemp, is as follows: (1) a basal gneissic series; (2) a series of schists and gneisses, with crystalline limestone; (3) igneous rocks of the gabbro type, intrusive in the first two series. All of these are overlain unconformably by Paleozoic sediments. This classification is tentative, and probably simpler than the one finally adopted is likely to be.

[1] Syenite-porphyry dikes in the northern Adirondacks, by P. H. CUSHING: Bull. G. S. A., Vol. IX, 1898, pp. 239-256.

[2] Report on the geology of Clinton county, by H. P. CUSHING: From the Fifteenth Ann. Rep. of the State Geologist, in Ann. Rep. of N. Y. State Museum, 1895, pp. 503-573.

1. The basic gneissic series appears in the western tier of townships of the county, with the exception of Clinton, Peru, and Ausable. The gneisses comprise several varieties, varying widely in texture and composition.

2. The series of schists and gneisses, with crystalline limestone, occurs only in Black Brook township. The limestone is coarsely crystalline, and much of it is quite pure, but very often it contains much green pyroxene.

3. The gabbros occur in three areas, which are outliers of the main gabbro massive of the Adirondacks. One is in Ausable township, extending north and west of Keeseville, and is the direct prolongation northeastward of a great gabbro ridge, which comes up to Keeseville from the southwest. The second forms Rand's Hill, in Beekmantown and Altona townships, twenty miles north of the first one. The third area forms the Catamount Mountain ridge, in southwestern Black Brook township.

After the intrusion of the gabbro, and prior to the Potsdam deposition, the region was subjected to intense metamorphism, resulting in the foliation and granulation of the rocks, with or without subsequent recrystallization.

Cushing[1] maps the boundary between the Potsdam and pre-Cambrian rocks north of the Adirondacks, from the line between Clinton and Franklin counties, west across Franklin county into St. Lawrence county, to a few miles west of Potsdam.

The sequence of rocks in the region is believed to be as follows:

1. A series of gneisses of great variety of structure and composition, in which all original structures are lost, of igneous origin, and in part at least of Archean age. They seem to grade into the basic gabbros of the region; at least the gabbros present phases not to be distinguished from the gneisses.

2. The Grenville series (Oswegatchie series) comprising quartzose gneisses and schists, quartz-feldspar-biotite gneisses, dioritic, and gabbroic gneisses, and occasional bands of coarsely crystalline limestone. These rocks are accompanied by belts of gneiss, similar to the older gneiss, which seem to be interstratified with the other rocks of this series, but whose relationships are doubtful. The gneiss of the Grenville series

[1] Report on the boundary between Potsdam and pre-Cambrian rocks north of the Adirondacks, by H. P. CUSHING: Sixteenth Ann. Rep. N. Y. State Museum, 1898, pp. 1-27. With sketch map.

differs in appearance from the older gneiss, and a considerable portion seems to be unquestionably of sedimentary origin, although dynamic metamorphism has obscured all traces of clastic structure and given the gneiss a foliation in common with the older gneisses, rendering the field relations obscure. From Parishville westward to Potsdam the Grenville series is more widely distributed, less faulted, and less completely metamorphosed, and hence with its sedimentary character less disguised, than the Grenville series farther east, probably because of its greater distance from the anorthosite intrusion. However, it seems to be beyond question that the eastern and western series are equivalent.

3. The anorthosite intrusion.

4. Later gabbros.

5. Granitic intrusions. The region was then subjected to intense dynamic metamorphism, after which occurred the intrusion of

6. Diabase and trachyte dikes.

7. Paleozoic rocks overlying unconformably all the preceding.

Kemp[1] continues his preliminary report on the geology of Essex county, N. Y., with an account of the detail geology of the individual townships. The additional observations have corroborated the conclusions reached in his previous report on this county,[2] concerning the main classification of the rocks of the area, although it is now doubtful if a sharp stratigraphic distinction can be drawn between Series (1) and (2).

Kemp[3] describes and maps the geology of the Lake Placid region in the Adirondacks of the northwest part of Essex county. Crystalline rocks of Algonkian age occupy a large part of the area. These include crystalline limestone, quartzite, granite, gneiss, and anorthosite. It is probable that some of the gneisses, and especially those associated with the limestones and quartzites, are altered sediments, and it is also probable that the gneisses with augen of labradorite are squeezed igneous rocks, but the investigation does not permit of their

[1] Preliminary report on the geology of Essex county, by J. F. KEMP: From the Fifteenth Ann. Rep. of the State Geologist, in Ann. Rep. of N. Y. State Museum, 1895, pp. 579-614. With geol. maps.

[2] See Report of State Geologist of New York for 1893, pp. 433-572. Summarized in Journal of Geology, Vol. VI., 1898, pp. 528-529.

[3] Geology of the Lake Placid region, by J. F. KEMP: Bull. N. Y. State Museum, Vol. IV., 1898, pp. 51-64. With geol. map.

separation. The anorthosites have intruded and metamorphosed the limestones and quartzites, and probably some of the gneisses. It has been noted that the anorthosite frequently passes outward by gradual transition into the dark gneisses with labradorite augen. Cutting all the above rocks are trap dikes, but whether pre-Cambrian or later, is unknown.

GENERAL COMMENT ON THE ADIRONDACK WORK

The above conclusions are of much interest as bearing on the general problems of the origin and age of the gneisses associated with the limestones of the Adirondack region. Kemp,[1] working on the eastern side of the district, has previously concluded that it does not appear certain that in the eastern Adirondack region there are any rocks older than the clastic series. As a result of field work on the eastern and western sides of the district, Van Hise[2] has held that most of the gneisses are clastic, but that a part of the red gneisses may be older than the clastic series, and therefore of Archean age. From the above summaries it appears that Kemp in his recent work still maintains the absence of the Archean. Cushing, working mainly in the northern part of the region, although overlapping Smyth's area a little way on the west, places in a lower series gneisses which he believes to be in part at least of Archean age, holds that a considerable portion of the gneisses associated with the limestones are unquestionably of sedimentary origin, and offers no evidence to show that any of the gneisses associated with the limestones are igneous and later than the limestone. Smyth, working entirely on the western side of the region, concludes that the presence of the Archean or basement gneiss has not been shown; that certain of the gneisses associated with the limestones may be sedimentary; but that the greater part of the gneisses of the district are igneous and later than the limestone. He thus agrees with Kemp on the point of the absence of the Archean.

It is to be remembered that Kemp, Cushing, and Smyth have been working in different areas. Each of them may be right as to the origin of the gneisses of his area and there may be present in the Adirondack district Archean, Algonkian, and post-Algonkian gneisses. Such is approximately the case in the Lake Superior region,

[1] Bull. G. S. A., Vol. VI., 1895, p. 251.

[2] Bull. 86 U. S. Geol. Survey, 1892, pp. 413-414, and sixteenth Ann. Rep. U. S. Geol. Survey, 1896, pp. 771-773.

where we have Archean and Algonkian gneisses and post-Algonkian granites.

While in different parts of the region the different conclusions above outlined have been reached, for the Adirondack region as a whole this much seems to have been shown. There is present a series of completely crystalline limestones and graphitic quartz-schists of sedimentary origin and pre-Cambrian age; closely associated with these are beds of graphitic and other gneisses, which are also sedimentary; cutting all the sedimentary rocks are gneisses of igneous origin, certain granites, and the great gabbro mass. That there is present a basal gneiss, while probable, has not been demonstrated. The question is still open. For much the larger part of the region also there remains for future work the discrimination of the sedimentary gneisses and the igneous gneisses of later origin.

The lithological similarity of the Adirondack sedimentary series with the Grenville series of the Original Laurentian district to the north has frequently been commented upon. In the latter district it has been possible lately to separate the sedimentary gneisses associated with the limestones from the true igneous gneisses of the Basement Complex by means of chemical analyses. The success of this method in the Original Laurentian district suggests that it may afford the best means for a satisfactory determination of the origin of the lower gneisses in the Adirondack district.

Miller[1] describes the occurrence of corundum in gneiss, syenite, and quartz-pegmatite of the Laurentian in the counties of Hastings, Renfrew, and Peterborough, in eastern Ontario.

Adams[2] reports on the geology of a portion of the Laurentian area lying to the north of the island of Montreal.

A previous report[3] summarized in this JOURNAL (Vol. VI., pp. 850-852), covers about the southeastern quarter of this area, and in a general way the conclusions reached for this southeastern area are applied to the larger area under discussion.

[1] Economic geology of eastern Ontario, corundum and other minerals, by WILLETT G. MILLER: Report of the Bureau of Mines, Ontario, Vol. VII., 1898, pp. 207-238.

[2] Report on the geology of a portion of the Laurentian area lying to the north of the island of Montreal, by FRANK D. ADAMS: Ann. Rep. Geol. Surv. of Canada, Vol. VIII., 1897, part J, pp. 184. With geological map.

[3] Ann. Rep. Geol. Surv. of Canada for 1894, Vol. VII., 1896, part J.

The Archean geology is summarized by the author as follows:

1. The Archean rocks in this area are of Laurentian age,[1] and are in part referable to the Grenville Series and in part to the Fundamental Gneiss.

2. The Grenville Series contains gneisses, as well as limestones and quartzites, which are of aqueous origin, having the chemical composition and the stratigraphical attitude of sedimentary rocks. With these are intimately associated, however, other gneisses which are of igneous origin.

3. The Fundamental Gneiss consists largely, if not exclusively, of igneous rocks in which a banding or foliation has been induced by movements caused by pressure.

4. Both series are penetrated by various igneous masses, of which the most important are great intrusions of anorthosite, a rock of the gabbro family, characterized by a great preponderance of plagioclase. This rock is in places perfectly massive, but generally exhibits the irregular structure which is so often observed in gabbros and which is brought about by a variation in the size of the grain or the relative proportion of the constituents from place to place. In addition to this original structure, the rock almost always shows a peculiar protoclastic, cataclastic or granulated structure which is especially well seen in the foliated varieties. This differs from the structure characteristic of dynamic metamorphism in the great mountainous districts of the world, having been produced by movements in the rock-mass while this was still deeply buried in the crust of the earth and probably very hot—perhaps near the melting point.

5. The same granulated structure is also seen in all those gneisses which have been formed from massive igneous rocks by dynamic movements.

6. The fine grained aqueous rocks of the Laurentian, on the other hand, have been altered chiefly by a process of recrystallization.

7. The "Upper Laurentian" or "Anorthosite Group" of Sir William Logan does not exist as an independent geological series—the anorthosite, which was considered to be its principal constituent, being an intrusive rock, and its remaining members belonging to the Grenville Series.

8. In all cases of supposed unconformable superposition of the

[1] In the sense of pre-Cambrian or Original Laurentian.

anorthosite upon the Laurentian gneisses, which have been carefully investigated, the unconformability is found to be due to intrusion.

9. The anorthosites are probably of pre-Cambrian age, and seem to have been intruded about the close of the Laurentian.

10. The Canadian anorthosites are identical in character with the anorthosites associated with the Archean rocks of the United States, Norway, Russia, and Egypt. The Norwegian occurrences, however, are probably more recent in age than those of Canada.

Adams and Barlow[1] give a general outline of geological work begun, but not yet finished, in the Laurentian of central Ontario, in the area comprising map sheets No. 118 and a portion of 119 of the Ontario series of geological maps, and indicate certain conclusions which seem likely to be reached concerning the origin and relations of the Grenville and Hastings series.

The Fundamental Gneiss occupies the northwestern, and by far the larger portion of the area. It consists of igneous rocks closely allied to granites, diorites, and gabbros, all showing more or less distinct foliation.

The Grenville and Hastings series are principally exposed in the southeastern portion of the area, the Grenville series appearing in a belt adjacent to the Fundamental Gneiss, and between the Fundamental Gneiss and the Hastings series.

The Grenville series is composed principally of gneisses identical in character with the Fundamental Gneiss, but it contains also, and is characterized by a small quantity of altered sediments, chiefly limestone. Some varieties of the gneissic rocks may owe their origin to the partial commingling of the sedimentary material with the igneous rocks by actual fusion. The strike of the foliation of the rocks of the series follows in a general way that of the Fundamental Gneiss. The Grenville series is believed to be a sedimentary series, later than the Fundamental Gneiss, which has sunk down into, and been invaded by, intrusions of the latter series when this was in a semi-molten or plastic condition.

The Hastings series is composed chiefly of thinly bedded limestones, dolomites, etc., cut through by great intrusions of gabbro, diorite, and granite. This series is believed to represent the Grenville

[1] On the origin and relations of the Grenville and Hastings series in the Canadian Laurentian, by F. D. Adams, and Alfred E. Barlow: Am. Journ. Sci., 4th ser., Vol. III, 1897, pp. 173-180.

series in a less altered form. That is, the Fundamental Gneiss, upon which the Hastings series was originally laid down, having at a subsequent time been softened by the influence of heat, and having under the influence of dynamic action eaten into and fretted away the overlying Hastings series, gave rise to an intermediate zone of mixed rocks which constitutes the Grenville series. The Grenville series may, however, represent only a portion of the Hastings series, and the work so far done has been insufficient to determine the stratigraphical position of this portion. It seems probable that the age of the Hastings series will be shown to be Huronian.

The Grenville and Hastings series are unconformably overlain by, and disappear to the south beneath, flat-lying Cambro-Silurian rocks.

Ells[1] gives a general account of the Archean of eastern Canada, including a review of the various classifications made by the earlier geologists, and their recent modifications. It is concluded that it is possible to reduce the great series of the so-called Laurentian rocks to two principal divisions, viz., a lower Basal or Fundamental Gneiss, in which all traces of sedimentation are wanting, and which may be regarded as representing in altered form some portion of the original crust of the earth; and a newer, secondary series, derived doubtless from the decay of the former, in which the evidences of clastic origin are manifest. On this basis the arrangement of the systems for eastern Canada would be as follows:

LAURENTIAN, NON-SEDIMENTARY

Basal or Fundamental Gneiss (Ottawa gneiss), representing in altered form the original crust of the earth, and the lowest known series of rocks; without evidence of sedimentary origin.

HURONIAN, PARTLY SEDIMENTARY AND PARTLY IGNEOUS

Grenville and Hastings series, comprising limestones, quartzites, gneisses, etc., of Ontario and Quebec, in the Ottawa district.

Schists and altered slates, chloritic and other crystalline rocks of the Eastern Townships of Quebec, and the Gaspé peninsula.

Felsitic and gneissic rocks of northern New Brunswick.

Gneiss, quartzite, and limestone, of the so-called Laurentian of southern New Brunswick, regarded as the equivalents of the Grenville

[1] Notes on the Archean of eastern Canada, by R. W. ELLS: Proc. and Trans. Royal Society of Canada, 2d series, Vol. III, 1897, Sec. 4, pp. 117-124.

and Hastings series, felsites and schistose rocks of the Coldbrook, Kingston and Coastal divisions, the apparent equivalents of the rocks of the Sutton Mountain anticlinal.

Felsitic and syenite rocks of eastern Nova Scotia and northern Cape Breton, with their associated crystalline limestones and serpentines.

CAMBRIAN

Cambrian slates, sandstones, and conglomerates.

General comment.—The succession and correlation proposed in the above papers by Adams and Barlow and by Ells are fundamentally different from the traditional one which has been held in Canada for many years. The first departure is in placing the Grenville and Hastings series as equivalent to the Huronian. Ells goes further and places with the Huronian all the sedimentary rocks of eastern Canada. This usage of the term Huronian restricts the Laurentian to the basal or fundamental gneiss. While the names are different, this is essentially the classification proposed by Van Hise in his Correlation Paper —Archean and Algonkian, in 1892. However, in place of Laurentian, he would use the term Archean. Also he would restrict the term Huronian to the rocks of the Original Huronian area and their equivalents. As it is impossible to be certain whether or not sedimentary series of eastern Canada not structurally connected with the Original Huronian are really equivalent to it, he has included the rocks above called Huronian under another name—Algonkian, a broader term covering all pre-Cambrian sedimentaries and contemporaneous eruptives, including the Keweenawan. The essential point, the existence of a non-sedimentary basal complex separated by a profound unconformity from a later pre-Cambrian series, partly sedimentary and partly igneous, is agreed upon.

Willmot[1] describes the geology of the Michipicoton mining division, which is limited on its eastern side by the 84th meridian, on the west by Lake Superior, on the south by latitude 47° 30′, on the north by latitude 48° 30′. Most of the rocks of the area belongs to the Laurentian and Huronian. The northern, eastern, and southeastern portions of the area are occupied by the Laurentian; the central and southwestern portions by the Huronian. The Laurentian is almost everywhere a fine

[1] The Michipicoton mining division by A. B. Willmot: Report of the Bureau of Mines, Ontario, Vol. VII, 1898, pp. 184–206.

grained gray gneiss, which often becomes granitic and coarser grained in texture. The Huronian rocks are most commonly massive diorites and diabases, and hornblende and chlorite-schists; less commonly, they are slates, felsites, quartzites, and sericite-slates. The Laurentian is frequently in eruptive contact with the Huronian.

In two areas, the Nipigon or Keweenawan rocks overlie the Huronian and Laurentian rocks. These areas are one two miles north of Cape Choyye and one on the peninsula of Gargantua.

Walker,[1] in 1897, describes the stratigraphy and petrology of the Sudbury nickel district of Canada. The oldest rocks of the district are gneisses of various kinds, which are regarded as of Laurentian age. Next in age to the gneisses is a belt of rocks consisting of quartzite, graywacke, amphibolite, mica-schist, phyllite, clay-slate, and altered volcanic breccia, which extends from the north shore of Lake Huron northeastward to Lake Mistassini, in the neighborhood of Sudbury, the belt being about twenty-five miles wide. The rocks of this belt are believed to be of Huronian age. The Huronian rocks have suffered severe metamorphism, and the original character of many of them cannot be made out. In and adjoining the Huronian belt are elliptical areas of later eruptive greenstone, in places intimately associated with and genetically inseparable from gneissoid and micropegmatitic granites. The nickel ore, principally pyrrhotite, occurs intimately intermingled with the eruptives, and is regarded as a concentration by differentiation from the eruptive magma. Cutting both the Huronian and the included nickel-bearing eruptives are masses of fine grained pinkish biotite-granite, sending apophyses into the surrounding rocks. This granite is found to have been intruded in two eruptions. The youngest rocks of the Sudbury district are olivine-diabases, which occur in dikes, cutting all the other rocks of the district.

Bell[2] reports on the geology of the French river sheet, which represents the country around the north end of Georgian Bay. Huronian rocks occupy the northwest corner of the sheet, and Laurentian rocks all the area to the southeast.

[1] Geological and petrographical studies of the Sudbury nickel district of Canada, by T. L. Walker, Q. J. G. S., Vol. LIII, 1897, pp. 40–66. With geol. map.

[2] Report on the geology of the French river sheet, Ontario, by Robert Bell: Ann. Report of the Geol. Surv. of Canada for 1896, Vol. IX, 1898, Part 1, pp. 29. With geol. map.

The Laurentian rocks in general resemble the Grenville series, which belong to the upper division of the Laurentian. They consist of red and gray mica and hornblende-gneisses in beds which can be traced with regularity for considerable distances, together with coarse hornblende and mica-schists and bands of quartz-rock with schistose partings. No limestones have yet been found among those rocks within the boundaries of the sheet, but in the Parry Sound district to the eastward, among similar strata, the writer has traced five bands of crystalline limestone like those of the Grenville series. The gneisses are distinctively stratified and regularly arranged in anticlinal and synclinal forms, according to the structural laws governing stratified rocks ; the average angles of dip are not steep, and in general, so far as their texture is concerned, the gneisses have the characters of altered sedimentary deposits. Cutting the granites are greenstone dikes, with an east and west direction.

The Laurentian rocks northwest of the Huronian area, outside of the area of the sheet, are considered to belong to the older division of the system.

The Huronian rocks comprise quartzites, sericite-, chlorite , hornblende-, and arkose-schists, clay-slates, graywackés, and dolomites. They have a general synclinal structure. The quartzites of the ridges northwest of Killarney form the southern side of the basin, and those of the Cloche mountains the northern side. Along the southern side of the major syncline are several subordinate folds. Associated greenstones are less conspicuous than in the Huronian rocks on the Sudbury sheet to the north. Those present are more largely developed in the tract on the south side of Lake Panache than elsewhere.

In the space between the Cloche mountains and the range which runs eastward from McGregor Point to Sturgeon Lake, including Bay of Is'ands, McGregor Bay, and the land thence eastward to the junction of the two chains, the rocks belong to a local division of the Huronian which may, for present convenience, be called the arkose series, with its associated rocks. Structurally this area would appear to occupy the central part of the synclinal area between the above-mentioned conspicuous quartzite ranges. Although various forms of arkose or graywacke are the prevailing rocks within this space, there are in different parts of it considerable quantities of gray quartzites and fine quartz-conglomerates, mixed agglomerates and breccias, sericitic and micaceous schists, impure dolomites and eruptive greenstones.

As to the origin of these rocks, the thick unstratified and brecciated graywacke or arkose may represent consolidated masses of volcanic ashes or mud with stones, which were thrown upon the land or into shallow water, while the stratified varieties may have consisted of similar ejectamenta, thrown into deeper water where they became arranged into layers as we find them. Some of these rocks, whether stratified or otherwise, may represent volcanic products which were originally thrown into the sea in a molten or heated condition and became broken up and almost completely disintegrated.

A study of the different phases of the graywackes and their associated rocks in this region would appear to prove that the former constituted the crude material from which both the quartzites and clay-slates were derived by the modifying and separating action of water. Again, by the action of time, pressure, heat, and other metamorphosing agents upon different varieties of graywacke, some of our granites, syenites, gneisses, and possibly other crystalline rocks, were probably formed.

Solid and slaty argyllites are found along Long Lake, an expansion of the Whitefish River, and slate conglomerates occur on both sides of Bear Lake and between Cat and Leech lakes. However, these rocks do not form a large proportion of the Huronian series in this district.

Impure magnesian limestones occur in the northern part of the Bay of Islands, in the northwest part of the township of Rutherford, and north of the area of the sheet near Lake Panache.

Between the Huronian rocks on the north and the Laurentian rocks on the southeast there is a belt of red granite, the Killarney belt, running from Badgely Island to Three-mile Lake. This granite is apparently of eruptive origin, and of later age than the quartzites. All along the line of contact with the Huronian the rocks give evidence of great disturbance. Huge portions, as well as many of moderate size, have been separated from both sides and have been mingled together and intermixed with finer débris, all being cemented into a coarse breccia.

The southeastern side of the Killarney belt of granite rests against the Laurentian gneiss, except in the interval from the southern point of George Island to the entrance of Collins Inlet, where a narrow belt of partially altered, fine grained, brittle, red and sometimes gray quartzite intervenes between the granite and the water of Georgian Bay. Further northeastward, or where the granite of the Killarney

belt comes into contact with the gneiss which prevails to the eastward, it is not always separated from the latter by a very distinct boundary. The rocks in some places pass into each other more or less gradually.

Barlow and Ferrier[1] discuss the relations and the structure of certain granites and associated arkoses on Lake Temiscaming. An examination of the contact of the granite and arkose shows a gradual and distinct passage of the granite into the arkose. Microscopically also there may be seen evidence of the decomposition of the feldspars of the granite, the breaking up of the feldspar and quartz, and finally the rearrangement and assortment of by water, indicating a gradual transition from the granite to the arkose.

The arkose is regarded as an Huronian sediment derived from and deposited on the granite. This is regarded as the only instance at present known in which the material composing the Huronian clastics can be clearly and directly traced both macroscopically and microscopically, to the original source from which it has been derived.

Comment.—The final statement is somewhat sweeping. Passing over the numerous instances of clear relations south of Lake Superior, it is necessary only to recall the instances close at hand, at Thessalon and Garden River, described by Irving, Pumpelly, and Van Hise, who found complete evidence of the unconformable relation between the Laurentian and Huronian, and of the derivation of the Huronian sediments from the Laurentian.

Burwash,[2] during the survey of the boundary line between the districts of Nipissing and Algoma in Canada, takes geological notes of the area traversed.

The run was made from south to north, from the upper waters of the Vermilion and Wahnipitae rivers, to within thirty-five miles of Lake Abittibi; and, with the exception of two areas of eruptive granite, the country was found to be underlain for the entire distance by Huronian rocks. The section is given in detail.

Tyrrell and Dowling[3] report on the country between Athabasca

[1] On the relations and structure of certain granites and associated arkoses on Lake Temiscaming, Canada, by A. E. BARLOW and W. F. FERRIER: Geol. Mag., Vol. V, 1898, pp. 39–41.

[2] Geology of the Nipissing-Algoma line, by EDWARD M. BURWASH: Sixth Rep. of the Bureau of Mines, Ontario, 1897, pp. 167–184.

[3] Report on the country between Athabasca Lake and the Churchill River in Canada, by J. B. TYRRELL, assisted by D. B. DOWLING: Ann. Rep. Geol. Surv. of Canada, Vol. VIII, 1897, Part D, pp. 120 with geol. map.

Lake and the Churchill River in Canada. The area covered by the report is bounded on the south by the Churchill and Clearwater rivers; on the west by the lower portion of the Athabasca River; on the north by Athabasca Lake, Stone River, with its expansions, Black and Hatchet lakes, Wollaston Lake, and Cochrane or Ice River; on the east by the lower part of the Cochrane River, Reindeer Lake, and Reindeer River.

Laurentian rocks, including hornblende-granites, biotite granites, muscovite granites, granitoid gneisses, gabbros, and norites, are found outcropping on the Churchill River from two miles below the mouth of the Mudjatick River eastward to the mouth of the Reindeer River; thence northward they occupy most of the eastern part of the district. Further west they are followed north to Cree Lake. In the northern part of the area they occupy most of the northern shores of Athabasca and Black lakes.

As far as at present known, the Huronian is represented in this district solely by three small areas on the north shore of Lake Athabasca. The Huronian here includes quartzites, calcareous sandstones and schists, conglomerate, hälleflinta, ferruginous chlorite-schists, and other green schists.

The Laurentian and Huronian are unconformably overlain by horizontal sandstones and conglomerates, called the Athabasca sandstone, which is placed in the Cambrian. However, these sandstones are similar to the sandstones found to the north associated with quartz-porphyries, diabases, etc., like those of the Keweenawan of Lake Superior, and there is little doubt that the two sets of rocks belong to the same horizon.

Tyrrell[1] reports on an exploration of the Doobaunt, Kazan, and Ferguson rivers northwest of Hudson Bay, the northwest coast of Hudson Bay, and on two overland routes from Hudson Bay to Lake Winnipeg.

Laurentian rocks, including granites, diorites, and granite and diorite gneisses, occupy a large part of the region crossed by the three main lines of travel—the Doobaunt River and Chesterfield Inlet, the Kazan and Ferguson rivers, and the west coast of Hudson Bay,—although their precise extent is unknown.

The Huronian rocks include three more or less distinct groups, the Marble Island quartzites, the greenish quartzites and graywackes, and

[1] Report on the Doobaunt, Kazan, and Ferguson rivers, and on the northwest coast of Hudson Bay, by J. B. TYRRELL: Ann. Rep. Geol. Surv. of Canada, Vol. IX, 1898, Part F, pp. 218. With geol. maps.

the more or less highly altered and often schistose diabases and gabbros. The largest area of Huronian is found along the coast of Hudson Bay from Baker's Foreland south to a point forty-five miles north of Cape Esquimaux, and inland for seventy miles up the Ferguson River. Other areas are found between Schultz and Baker lakes, near Lake Angikuni, near Kasba and Ennaidai lakes, the north shore of Doobaunt Lake, and the east shore of Wharton Lake.

The Huronian rocks are overlain unconformably by the Athabasca sandstone. As this sandstone is older than the flat-lying Cambro-Silurian limestone, and unconformably above the Huronian, it is assigned to the Cambrian, although no fossils were found in the formation. Lithologically the whole terrane presents a remarkable resemblance to the red sandstones and Cambrian quartz porphyries of the Keweenawan rocks of Lake Superior, and the two terranes are regarded as holding essentially similar positions in the geological time scale.

Low[1] reports on his explorations of the Labrador Peninsula, along the East Main, Koksoak, Hamilton, Manicuagan, and portions of other rivers. Laurentian rocks occupy nine tenths of the area of the Peninsula. They include gneisses and schists, some of clastic origin, some of eruptive origin. The clastic portion is in nearly all cases the oldest.

The Huronian rocks comprise beds of arkose, conglomerate, limestone, shale, slate, sandstone, chert, quartzite, mica-schist, and eruptives, in part at least contemporaneous with, and at present represented by, schists characterized by chlorite, epidote, altered hornblende, hornblende, sericite, and hydromica; also diabases, diorites, and various granites. They occur in two large areas and several small ones. The large areas are along the East Main River from near the mouth inland for 160 miles, and the area of the large lakes southwest of Lake Mistassini.

The Laurentian and Huronian rocks are overlain with strong unconformity by a series of rocks classified as Cambrian, comprising arkose, sandstone, limestone, dolomite, felsitic shale, argillite, and argillaceous shale, together with gabbro, diabase, fine grained, decomposed traps,

[1] Report on explorations in the Labrador Peninsula, along the East Main, Koksoak, Hamilton, Manicuagan, and portions of other rivers, in 1892, 1893, 1894, and 1895, by A. P. Low: Ann. Rep. Geol. Surv. of Canada, Vol. VIII, 1897, Part L, pp. 387. With geol. maps.

and volcanic agglomerates. The fine grained traps are interbedded with the clastic rock. No acid eruptives appear. On the east coast of Hudson Bay and at Chateau Bay near the eastern entrance of the Strait of Belle Isle, some of the traps have formed overflows on the surface, and are now represented by dark green, fine-grained melaphyres having large amygdaloidal cavities filled with quartz and agate. No fossils have been found in these supposed Cambrian rocks and their precise age and equivalency can only be conjectured. However, the mode of occurrence of thick beds of magnetic iron ore overlain by cherty, nonfragmental carbonates in this series, closely resembles that of the iron ores of the Lake Superior region described by Irving, Van Hise, and others. This, with other characters of resemblance, renders it almost certain that the two developments represent the same period, or, in other words, that the Animikie rocks of Lake Superior, assumed to be Lower Cambrian, are equivalent to the rocks here described as Cambrian in Labrador.

Low[1] reports on a traverse of the northern part of the Labrador peninsula, from Richmond Gulf to Ungava Bay. Laurentian rocks occupy the greater part of the area. These are chiefly granites, more or less foliated. They are of different ages, but, except in a few cases, they cannot be discriminated. Cutting them are intrusive diabases.

Intimately associated with the granites is a series of more or less quartzose mica-gneisses and mica-schists, interbanded with hornblende-schists and hornblende-gneisses; and at times with quartz-magnetite gneiss. These gneisses and schists are supposed to represent a bedded series of rocks somewhat similar to the Grenville series. While most of the schists are thus probably very ancient, others may be of the same age as the Cambrian.

Cambrian rocks were met with along the east coast of Hudson Bay, to the northward of Cape Johns, and on the Larch River from its junction with the Kaniapiskau upwards for thirty miles. A section examined on the east side of Castle peninsula, on the north side of the outlet of Richmond Gulf, presents rocks closely resembling the Mesnard quartzites and the Kona dolomites of the Lower Marquette series of the south shore of Lake Superior, capped by a later outflow of trap, classed as Algonkian by Van Hise.

[1] Report on a traverse of the northern part of the Labrador peninsula, from Richmond Gulf to Ungava Bay, by A. P. Low: Ann. Rep. Geol. Surv. of Canada for 1896, Vol. IX, 1898, Part L, pp. 1-43. With geol. map.

Comments.—In the explorations by Tyrrell and Low, considering the time available and the ground covered, the determination of the geological series was necessarily of the most hasty nature. Nothing but the roughest petrographical discriminations could be made, and no structural work was possible. Their terms Laurentian, Huronian, and even Cambrian, therefore, indicate only the broad petrographical features of the rocks traversed, and do not stand for well defined series equivalent to the series so named to the south.

Following the usage of many of the Canadian geologists, the Cambrian is made to include rocks supposedly equivalent to the Cambrian, Keweenawan, and Animikie of the Lake Superior region, and Low carries it down even to include formations similar to Lower Marquette formations of the Lake Superior country. In the Lake Superior region, where most thoroughly studied, the Keweenawan and Huronian formations are separated from each other and from the Cambrian by well marked unconformities, unconformities uniformly recognized by geologists who have done close work in this region. These unconformities have been recognized also in other parts of North America. If the rocks above called Cambrian are really equivalent to the various Lake Superior series mentioned, then the extension downward of the Cambrian, across well established unconformities, to include such series, has no reasonable basis. However, in view of the scanty observations and the absence of connecting structural work, any correlation at present is little more than a suggestion, and for this reason it would be better to give the formations local names, as was done by Tyrrell in the case of the Athabasca sandstone. Thus would be avoided the confusion arising from the misuse of well defined and well established terms like Cambrian, Keweenawan, and Huronian.

Bailey[1] reports on the geology of southwest Nova Scotia. Cambrian rocks devoid of fossils occupy a large part of the area. The succession is, in ascending order, as follows:

I. Quartzite Division.
- (*a*) Heavily bedded bluish quartzites, alternating with much thinner beds of argillite.
- (*b*) Greenish-gray sandstones or quartzites, somewhat chloritic and less massive than in (*a*), and alternating with slates which are arenaceous below but become progressively more argillaceous above.

[1] Report on the geology of southwest Nova Scotia, by L. W. BAILEY: Ann. Rep. Geol. Surv. of Canada, Vol. IX, 1898, part M, p. 154. With geol. map.

II. Banded Argillite Division.

(*a*) Greenish-gray slates, becoming bluish or light gray, and passing upwards into

(*b*) Purple slates, marked in the lower beds by pale, yellowish-green seams, with faint bedding lines, which are wanting in the higher beds.

(*c*) Bluish-gray and gray slates, often with cloudings of green, purple, lilac, buff, or yellow, in places exhibiting a conspicuous banding or ribboning of the beds.

III. Black Slate Division.

Black, with some blue or gray slates, often studded with cubes of pyrites, and very rusty-weathering.

Comment.—Here again the Cambrian has been extended downward to cover rocks, devoid of fossils, which have been mapped as Algonkian by Van Hise.[1]

Dawson[2] presents a brief note on Cryptozoon and Archæozoon found in the pre-Cambrian. A general discussion is given of the biological affinities of the Cryptozoon and Archæozoon, and descriptions are quoted of younger forms which may be the successors of the pre-Cambrian forms.

Dawson,[3] in an account of the physical geography and geology of Canada, sketches the distribution and characters of the pre Cambrian rocks.

Dawson[4] gives a general account of the pre-Cambrian rocks of Canada. This is largely a discussion of pre-Cambrian classification and nomenclature, based on a review of early and recent work on the pre-Cambrian of Canada, and will, therefore, not be fully summarized. A few of the more important conclusions may, however, be mentioned.

The Laurentian still includes both Fundamental Gneiss and the Grenville series.

[1] Bulletin 86, U. S. Geol. Survey, Pl. V. Sixteenth Ann. Rept., Pl. CVIII.

[2] Note on Cryptozoon and other ancient fossils, by SIR WILLIAM DAWSON: Canadian Record of Sci., Vol. III, pp. 203–219.

[3] The physical geography and geology of Canada, by G. M. DAWSON: Handbook of Canada, issued by the Publishing Committee of the Local Executive of the British Assoc., Toronto, 1897.

This is largely a general summary of the present state of knowledge concerning the geology of Canada, and will therefore not be fully reviewed.

[4] Presidential address to the geological section of the British Association for the Advancement of Science, by G. M. DAWSON: Proc. Brit. Assoc. Adv. Science for 1897, Section C, p. 13

The Huronian proper, under whatever local name it may be classed, still remains a readily separable series of rocks.

The Upper Laurentian, Labradorian, Norian, or anorthosite group is found to consist essentially of intrusive rocks, later in age than the Grenville, but in all probability pre-Paleozoic.

The general tendency in our advance in knowledge appears to be in the direction of extending the range of the Paleozoic downward, whether under the old name of Cambrian, or under some other name, applied to a new system defined, or likely to be defined, by a characteristic fauna; and under Cambrian, or such new system, if it be admitted, it is altogether probable that the Animikie and Keweenawan rocks must eventually be included.

The introduction of the term Algonkian, proposed to include the recognizable sedimentary formations below the Olenellus zone, and their igneous equivalents, is believed to be a backward step, for the following reasons: It detaches from the Paleozoic great masses of conformable and fossiliferous strata beneath an arbitrary plane and unites these under a common systematic name with other vast series of rocks, now generally in a crystalline condition; it includes as a mere interlude, what, in the region of the Protaxis, is one of the greatest gaps known to geological history; and it does not in the least degree remove the difficulty found in defining the base of the Grenville series.

Comment.—The statements that there is a general tendency to extend the term Paleozoic downward as our knowledge advances, and that the introduction of the term Algonkian is a backward step, would not be agreed to by the United States geologists. However, this subject is too complex to be discussed in the space at our disposal. Those interested are referred to Bulletin 86 of the U. S. Geol. Survey, and to the Principles of North American pre-Cambrian Geology in the Seventeenth Annual Report of the U. S. Geol. Survey.

MADISON, WIS. C. K. LEITH.

REVIEWS

West Virginia Geological Survey. Vol. I. By I. C. WHITE, State Geologist.

The Geological Survey of West Virginia was established, with a small appropriation, by an enactment of the legislature of that state passed in February, 1897. Dr. I. C. White was appointed state geologist and he entered upon the active duties of his office January 1, 1898. The present volume is the first publication of the survey and in it is incorporated a part of the results of investigations prosecuted during 1898.

The report is a paper covered octavo volume of 392 pages and consists of four parts. Part I (pp. 1–26) is a "Report of the State Geological Commission to the Legislature, containing an account of the operations of the survey during the years 1897 and 1898." Part II (pp. 27–53) is entitled "Levels above Tide." It is a compilation of the elevations of the several stations on all the principal railroads of the state, the data for which were contributed by the officers of the roads.

Part III (pp. 54–122) upon the "Variation of the Magnetic Compass" and "True Meridian Lines in the Several Counties of the State" was prepared by R. U. Goode, Geographer, United States Geological Survey in coöperation with the state survey. Meridian monuments were placed in the county seats of each county in the state, and detailed descriptions of the location of the monuments are given in this paper.

The major part of the volume (Part IV, pp. 123–378) is devoted to a report on "Petroleum and Natural Gas" by the state geologist. The report is opened with a historical sketch which is followed by an account of the geology of petroleum and natural gas. A large amount of information which will be of great value to the oil and gas industry of the state is here published.

It is unfortunate that the volume should contain no index, but, as stated by the state geologist, it had to be omitted because of the

lack of sufficient funds. It is to be desired that the State of West Virginia may see fit to continue the work of their geological survey so well begun, by appropriating for it sufficient funds to carry out the work as outlined by the state geologist in Part I of this volume.

S. W.

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